JANUARY 1987 $3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone 0344-884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, (No. 402498). Registered office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

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Vol. 29 No. 1 January 1987

Front cover: Hotol is a totally new European concept in space launch vehicle concepts with horizontal take-off, air breathing engine and full recoverability. It was conceived in order to achieve a significantly reduced launch cost to orbit and to play an important role in supporting the Columbus Space Station programme. Potentially it offers a key launch system for the development of Space at the beginning of the 21st Century having both unmanned and manned modes of operation. Currently, Hotol is at the 'proof of concept' stage, involving studies into a wide range of new technical problems. *BAe*

Into Orbit At Lower Cost

Cheaper access is the key to the future commercial development of Space. The European Space Agency (ESA) has accepted this challenge and aims to enter the 21st century with economical launch means at its disposal.

Many new technologies are involved which ESA will be starting to fund in 1987 in order that project development may start by 1990.

Britain's ideas are represented by Hotol, a single-stage spaceplane capable of delivering seven to eight tonnes of payload to orbit. As Europe looks to the future, *Spaceflight* highlights the present status of the Hotol concept in this issue.

EUROPEAN RENDEZVOUS

UK Plan for a European Spaceplane

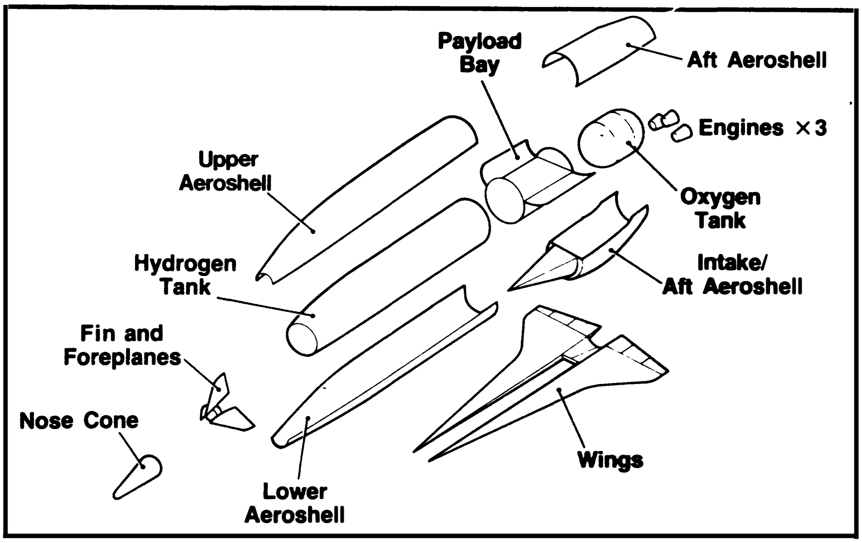
The European Space Agency (ESA) is expected to start a programme in the spring of this year that will lead to a decision on the form of launch vehicle to follow Ariane 5, according to information presented at the recent British Interplanetary Society "Hotol" Symposium in London.

The ESA Council, at its meeting in October 1986, gave wide acceptance to a proposal for a three year programme to select a concept and identify areas of technical development. It is now expected that the Council will agree to a definition programme for the next launcher generation before the middle of this year.

Mr. Roy Gibson, Director-General of the British National Space Centre and a former Director-General of ESA, told Symposium delegates that a "significant amount" of ESA money should be reserved for the next generation launcher.

A key element to future space commercialisation is a significant reduction in launch costs and it is envisaged that the fully recoverable spaceplane will be the means of achieving this by the start of the next century.

The UK plan for a European spaceplane is Hotol (horizontal take-off and landing) and this is now midway through a two year proof-of-concept study.



Hotol structural breakdown.

Mr. Gibson stressed that the UK was not looking at Hotol as a "nationalistic flagship".

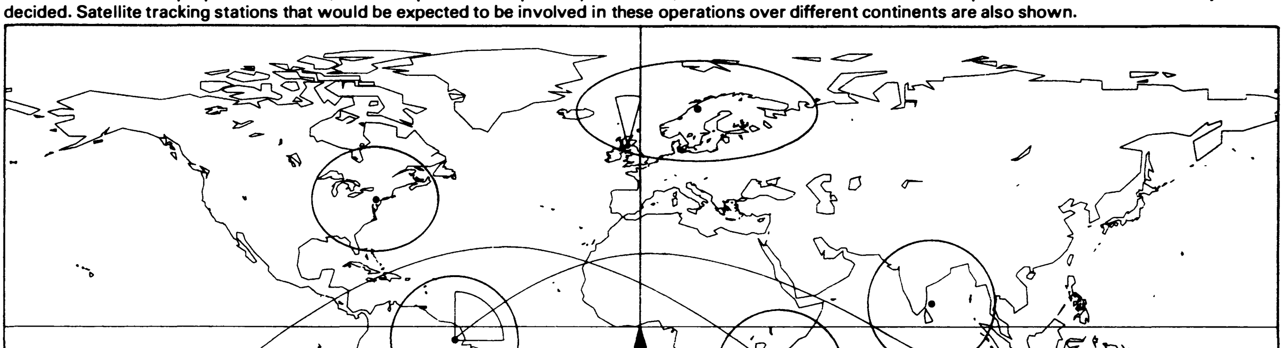
"This is not our policy and I have personally criticised other countries when, in similar circumstances, they have pushed their own point of view in this way," he said.

Hotol Studies

The £3 million proof-of-concept study has been jointly funded by the British National Space Centre (BNSC) and the two companies currently involved, British Aerospace and Rolls Royce.

The Hotol spaceplane concept relies on the development of a new propulsion technique, currently being pursued by Rolls Royce, which would allow the engines to use atmospheric oxygen for the first stage of the journey before switching to onboard liquid oxygen supplies. This would lead to a significant reduction in onboard propellant mass, permitting the use of wings to optimise the initial flight

Two launch sites are proposed for Hotol, one an equatorial site possibly at Kourou, French Guiana and one in NW Europe at a location that also has yet to be decided. Satellite tracking stations that would be expected to be involved in these operations over different continents are also shown.



trajectory after takeoff from a standard-length runway.

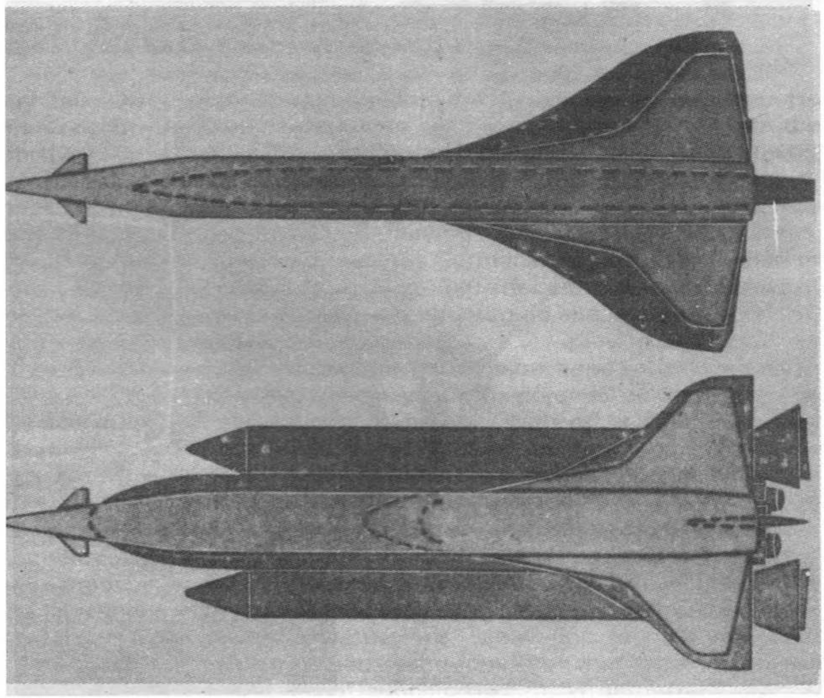
The vehicle emerging from the design boards is operationally part aircraft and part spacecraft, being slightly larger than Concorde with a similar take-off mass and payload capability. It is smaller than the US Space Shuttle (see diagram), but shares the same diameter of payload bay.

Most of the forward fuselage would be occupied by a large pressurised liquid hydrogen fuel tank with a smaller liquid oxygen tank located at the rear behind the payload bay.

The studies on Hotol and the engine, designated RB545, are examining the feasibility of carrying a load direct to space from a runway without the need for rocket launch facilities or major preparation lasting many weeks.

The basic design aims of Hotol are to produce a vehicle that is capable of putting a standard communications satellite weighing around seven tonnes into low Earth orbit at one fifth the cost of present launch systems. The ability to dock with Space Stations and recover satellites is also being investigated.

Designers confidently predict that Hotol will reduce launch costs to low Earth orbit by a factor of five and will halve the cost of putting a satellite into geosynchronous orbit.



Comparisons: (*above*) Hotol and Concorde; (*below*) Hotol and the US Orbiter. Hotol outlines are shown in the lighter shading.

Manned Operations

In the first instance, Hotol would be developed as an unmanned, automatic vehicle, but it would be capable of adaptation for manned missions with the inclusion of a pressurised module in the payload bay. However, even on a manned mission the human occupants would play no part in the launching and landing activities.

Manned missions would only take place after the unmanned version of Hotol was fully proved and it is envisaged that one vehicle from a fleet of five or six would be dedicated for this purpose.

On present forecasts Hotol will not need thermally insulating tiles like the Space Shuttle for protection during re-entry into the atmosphere. Instead, large skin panels (measuring one foot by three feet), which would not require periodic replacement, would be used. These would be made from carbon carbon material on areas of high temperature such as leading edges and from a Titanium/Rene 41 nickel sandwich on low temperature areas.

Laser Guided Takeoff

The mass at takeoff would be some five times that at landing (compared to about twice for a conventional aircraft) giving rise to a substantial disparity between undercarriage requirements for takeoff and landing. So it is currently being proposed that Hotol be launched from a laser guided trolley, with a light-weight undercarriage provided for landing.

A take-off speed of 290 knots would be achieved with an acceleration of 0.56g and a run of 2300 m. Vertical acceleration at lift-off would be 1.15g with a climb attitude of about 24 degrees.

Hotol would go supersonic after two minutes, clearing commercial air lanes (12,000m) after 4.5 minutes and reaching a speed of Mach 5 after just nine minutes. The fuel burned up at this point would be about 18 per cent of take-off mass, compared to a typical value of 50 per cent for a vertical take-off vehicle.

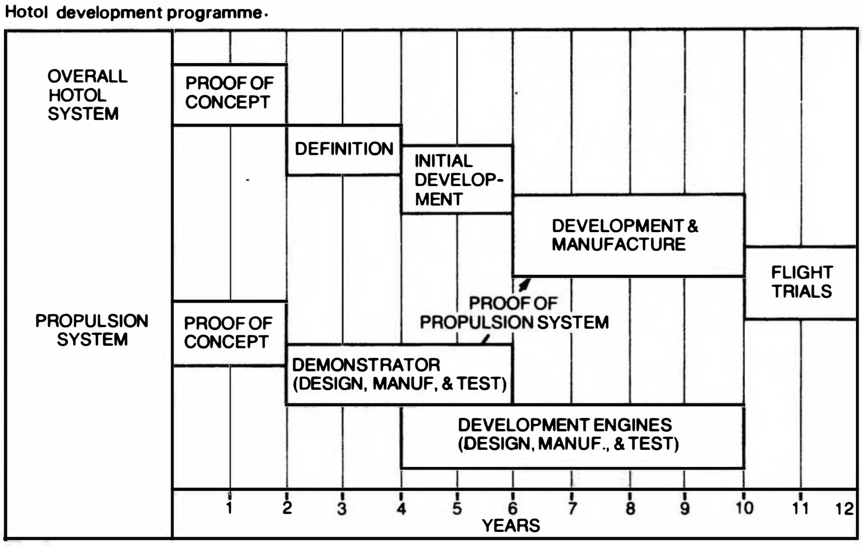
At the nine minute point external air-breathing would no longer be possible and a ballistic trajectory would begin. Orbital velocity would be achieved at 90 km, the main engine would then cut off and Hotol would coast to an operating altitude of around 300 km.

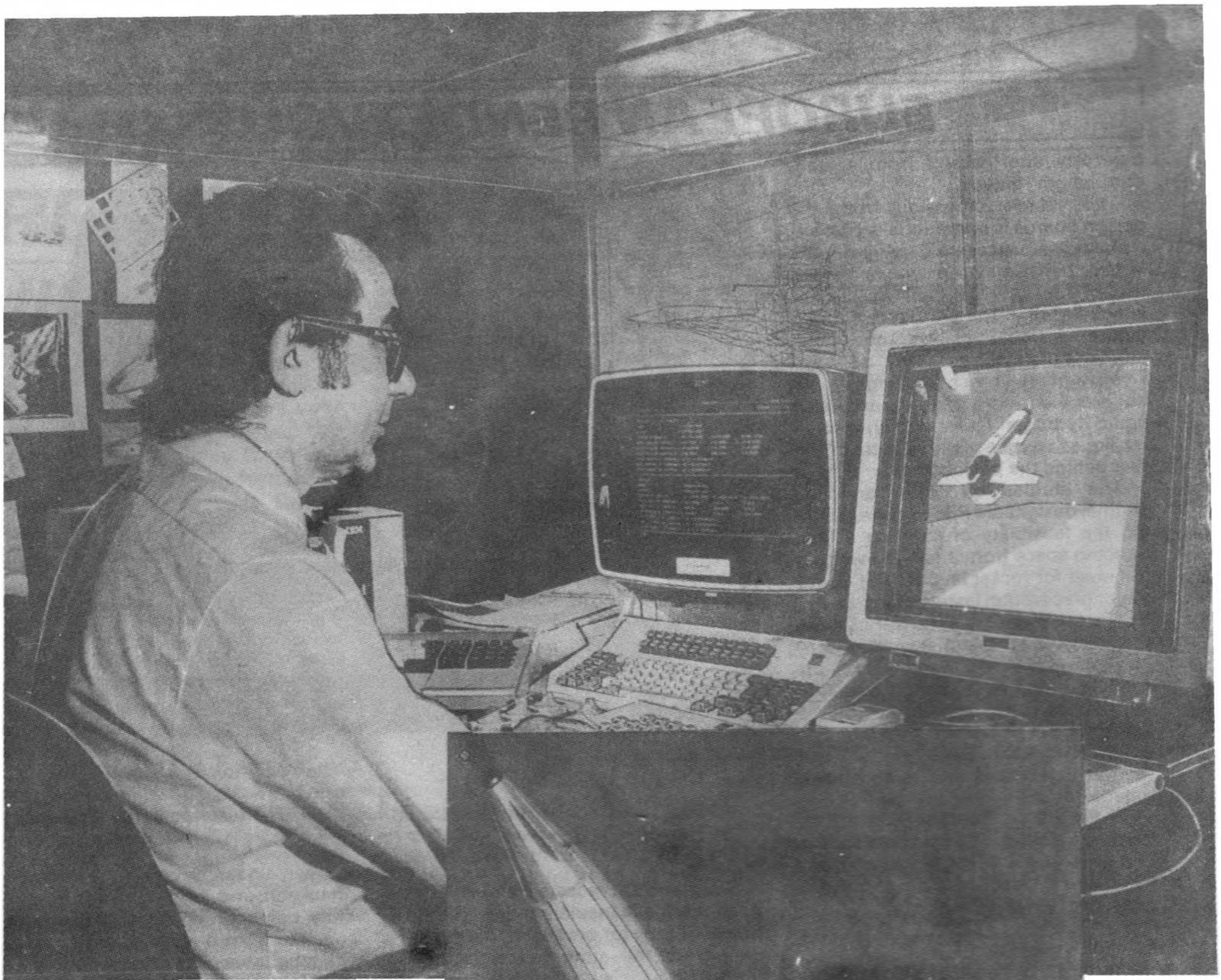
Maximum mission duration would be 50 hours with position and altitude changes achieved by an orbital manoeuvring system (OMS).

At the end of its mission the OMS would slow the vehicle and bring the perigee down to about 70 km altitude in preparation for re-entry.

Hotol would re-enter the atmosphere at a very high incidence (about 80 degrees), reducing as speed falls and leading into a hypersonic glide at about 25 km altitude.

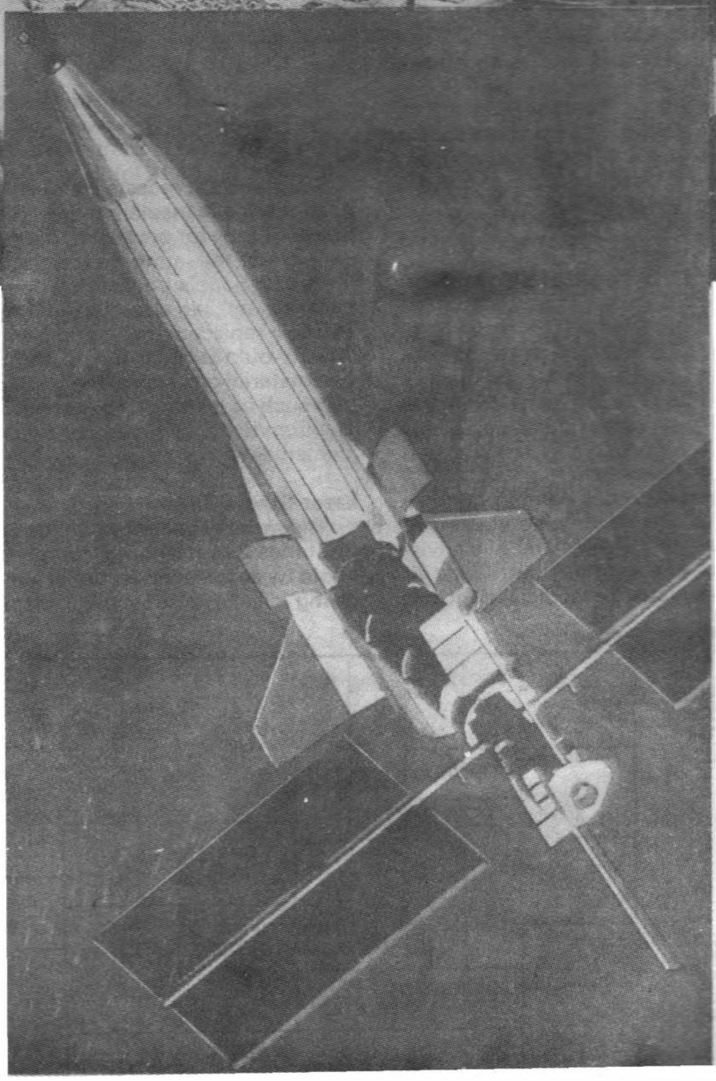
Hotol development programme.





Computer Graphics Aid Hotol Design

Above: A 3D computer aided terminal is being used to simulate Hotol in take-off attitude. The take-off speed of 320 mph (145 m/s) is achieved after a ground roll of 7,500 ft (2,300 m). The take-off mass is 230 T and the take-off acceleration is 0.6 g. The vehicle goes supersonic within 1.5 minutes and clears commercial airlanes (at 40,000 ft or 12 km altitude) after five minutes.



Right: A computer graphics representation of Hotol docking at the Columbus Space Station for a servicing mission. Hotol is designed primarily to give low-cost access to near-Earth space and this is achieved by automatic onboard control systems which dispense with the need for a crew. For servicing Europe's Columbus Space Station, a manned capsule would be fitted into the payload bay.

130 Attend Hotol Meeting

Hotol, the British concept for a Horizontal-Take-Off-and-Landing spaceplane, will be a major feature of Britian's Space Plan due to be announced shortly.

Speaking at the opening of the British Interplanetary Society's 'Hotol' Symposium on November 20, Roy Gibson, the Director-General of the British National Space Centre said: "Hotol comes at a time when we can play a positive role in Space and put forward our own proposals instead of just reacting to other people's, as we have been doing for the last 10 years."

Mr. Gibson confidently expressed BNSC's views on the importance of Hotol for the future of Space. Following its foundation a year ago (exactly to the day of the symposium), the BNSC sponsored Hotol as its first major project with a 50 per cent contribution to the funding of 'Proof-of-Concept' studies.

According to Mr. Gibson there can be no future for the commercialisation of space unless launch costs come down and the required cost reductions cannot be achieved by the improvement of conventional launch vehicles. BNSC, therefore, intends to be responsive to the Hotol project, to which Industry has now decided to give top-level backing.

Mr. Gibson made it clear that it was not BNSC's policy to keep Hotol as a purely British development. He criticised newspaper articles for suggesting that the UK do this while glossing over the scale of the costs involved. "The ESA Council was informed in June 1986 of our wish for truly cooperative involvement in Hotol and we are soon to make representations on how the project could be Europeanised," he said.

Of ESA's future programme, Mr. Gibson said that a key element would be launcher development. He wanted people to get away from the feeling that the question to be settled was one of 'Hotol versus this-or-that' and to evaluate Hotol in its own right. From mid-1987, work should be concerned with evaluating the concept and identifying the key technologies involved. There would be the Germans and others with ideas to contribute. Around 1990 a decision could then be taken for project development to go ahead over the next 10 years.

In conclusion, Mr. Gibson hoped that, within the next two to three years, the potential of Hotol would be seen by Civil Aviation. "With other space projects, such as Giotto, you see a beginning and an end," he said, "but not with Hotol. We have to begin to prepare the ground for its future possibilities."

Peter Conchie, Director of Business, British Aerospace spoke next on the 'Background to Hotol' and paid a special tribute to members of the British Interplanetary Society who had evolved the Hotol concept in informal discussions. Motivation for this work had been provided by the conviction that 'there had to be a better way of launching expensive hardware into orbit' – other than by conventional means which had evolved from the quite different considerations governing ballistic missile development.

In 1983 studies began at British Aerospace and Rolls Royce leading to the Hotol announcement at Farnborough in 1984. A small group of people had studied how the requirements of space users and customers could best be met and to what extent 'lateral thinking' from Concorde could contribute. Key deci-

sions quickly – atmospheric speeds not to exceed Mach 5, operating costs to be 20 per cent of those of the US Space Shuttle, protection against atmospheric heating to be by metal shingles and not ceramic tiles, and a single-stage-to-orbit vehicle to provide total reusability and make maximum use of atmospheric oxygen. For an adopted payload weight of seven to eight tonnes, which covers the biggest market requirement, the vehicle comes out to be somewhat bigger than Concorde, with larger wings, and would climb to Mach 5 at 85,000 feet at which point a switch would be made from atmospheric oxygen to onboard liquid oxygen for the hydrogen-oxygen combustion system.

In May 1985 documented proposals were presented to the Government, following which the BNSC-sponsored Proof-of-Concept studies began. Mr. Conchie emphasised that the project had to be a European undertaking and that ESA should be starting a related technology programme in 1987.

Challenger Impact on European Projects


The computer terminal used to process Giotto's camera signals.

Long delays, constraints or even abandonment will be experienced by many European space projects as a result of the Challenger accident.

The seriousness of the situation came to light at a recent Press Conference held at the Cologne-Porz Centre of the German Aerospace Research Establishment (DFVLR) in the presence of Minister Riesenhuber, the German Minister for Research and Technology, and attended by representatives of DFVLR and ESA and by astronaut E. Messerschmitt. The occasion was the inauguration of the microgravity user support centre (MUSC) dedicated to the support of new (industrial) experimenters. Especially affected will be projects related to microgravity research in the fields of Materials Science and Life Science.

In this report, which has been specially prepared for ***Spaceflight,*** BIS member ***Armin Cordel*** updates the status of several major European projects.

EURECA

Launch of the EURECA retrievable platform whose first mission is dedicated mainly to microgravity research, will be shifted from 1988 to April 1991. The flight unit is currently being integrated by MBB and a second one may be built for use in conjunction with the international Space Station.

The delay of the next EURECA flight and the availability of only three Shuttle Orbiters until the assembly of the Space Station means that flights of EURECA might become the exception rather than the rule. Any contraction of the EURECA programme would be especially significant for potential industrial experiments.

EURECA is based on the retrievable space pallet SAPS 01, which was released from STS-7 in 1983, and has a design lifetime of 10 years (see ***Spaceflight*** Sept/Oct 1986, p.365).

Spacelab Missions

After the successful Spacelab D1 mission in October 1985, DFVLR planned a further three missions at roughly two-yearly intervals before the launch of the international Space Station.

At present, these plans seem to be rather optimistic. NASA has postponed the planned launch of the Spacelab D2 mission from 1988 to the third quarter of 1991. This, according to DFVLR, "severely endangers the base of the German space programme". The delay will also be detrimental to Europe in general in the important field of Materials Science as ESA is considerably involved in the proposed Spacelab flights.

EUROPEAN RENDEZVOUS

Columbus Module

A final decision concerning European participation in the Space Station is to be taken in the Spring of 1987, provided agreement is reached by then. Present negotiations between ESA and NASA concern the use to which the Columbus Module is to be put. NASA would like it to be used exclusively for the Life Sciences, whereas ESA intends it for the Material Sciences as well.

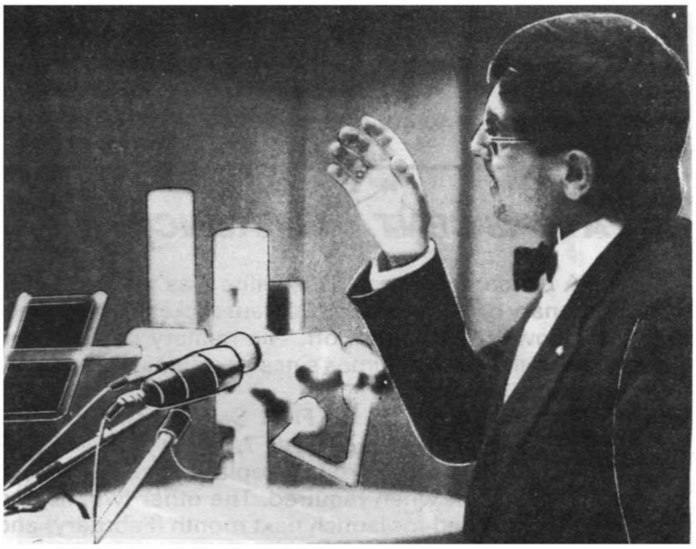
Although the European Columbus Module attachment to the Space Station is officially scheduled to be launched by 1994, NASA is considering delaying the launch until 1996/97.

European Space Autonomy

Minister Riesenhuber explained that he did not intend to decrease the German share (38 per cent) of the Columbus programme in view of European moves to autonomy in space. A man-tended free flyer to be launched by an Ariane 5, together with an ESA data relay satellite system comparable to NASA's TDRSS, would be a major step towards European autonomy in space experimentation.

In the Minister's view, studies on Ariane 5 and the cryogenic HM-60 engine to used for its first stage are now well advanced. His ministry will soon be deciding on support for Hermes and a final European decision on the development of Ariane 5/HM-60 and Hermes is expected to be taken later this year.

Germany supports a 20 per cent share of Ariane 5 covering essentially the second stage (as on previous Ariane versions) and the combustion chamber of the large HM-60 engine. German support for Hermes is likely to fall within the 10 to 30 per cent range of the assumed cost of £3 billion.



Minister Riesenhuber speaking at the Press Conference at the Colgone-Porz Centre of the German Aerospace Research Establishment.

With regard to a successor to Hermes, the Minister considered the Sanger project of a two-stage, fully reusable spaceplane to be an alternative to Hotol that was at least worth thinking about. "Technical breakthroughs are required for both Sanger and Hotol and at the present time these are not easy to calculate", he said.

Future British Space Policy

Possible trends for future British space policy were discussed at a meeting of the British Interplanetary Society on November 26, 1986. The speaker was Dr. T. L. Roberts, the Director of Planning and Finance at the British National Space Centre (BNSC).

At the time Ministerial decisions on the Space Plan submitted by the BNSC were still awaited and on the future levels of funding. Dr. Roberts therefore reviewed the sorts of questions that the Plan raised and some of the reasoning behind it.

In 1985 Britain spent about £100m. on civil space. This was less than Italy and comparable to India and Canada. It was one-fifth the French spend. About three-quarters of the UK money goes in support of ESA programmes, leaving a very small national programme indeed, compared with other European countries.

Mr. Roberts said a BNSC priority was to maintain the UK's position in communications satellites, going for the most commercial area of the market. This business area has been the most successful in the past. However, the concentration has tended to be upon the leadership of satellite programmes and the UK has lost much of its technology base. In the future in communications satellites the UK must secure its ability to build payloads. A continuing need is seen for mobile services, where other alternatives such as fibre optics are not feasible. Systems for ships, aircraft and other vehicles will become increasingly important.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

ATLAS CENTAUR LAUNCH

A US communications satellite was put into geostationary orbit by an Atlas Centaur rocket on December 4 following a night lift-off. The military payload had been delayed eight times since its original launch date of May 22, 1986.

The FltSatCom (Sixth Fleet Satellite Communications Spacecraft), designated F7, is one of three being inserted into parking orbits to replace currently operating spacecraft when required. The other two, F6 and F8, are planned for launch next month (February) and in May.

UPPER STAGE SELECTED

NASA has selected the Inertial Upper Stage (IUS), a launch vehicle which fits in the cargo bay of the Space Shuttle, to carry probes to Jupiter, Venus and the Sun. However, an option was being kept open until early this year to fly one of these missions on a Titan IV.

NASA Administrator James C. Fletcher selected the upper stage, built by Boeing Aerospace, for three planetary missions – Galileo, Magellan and Ulysses – to be launched in 1989 and 1990. These missions will be the first to employ an IUS to carry payloads to study other bodies in the Solar System.

Each of the planetary payloads will use a standard two-stage IUS, with the exception of Ulysses – a probe to study the poles of the Sun – which will require the addition of a Payload Assist Module, built by McDonnell Douglas. The added module, a smaller "kick" stage, will be needed for additional energy to reach proper orbit around the Sun.

Ulysses is a joint mission of NASA and the European Space Agency (ESA). It has been funded and built by ESA.

The IUS is a two-stage, 17-foot-long vehicle weighing more than 16 tons. It was designed for both Earth-orbital and planetary missions and has already been employed to carry payloads to geostationary orbit.

The Magellan mission will orbit Venus and map its surface with radar and Galileo will orbit Jupiter for nearly two years and sending down an atmospheric probe. The retropropulsion system for the probe's descent into the Jovian atmosphere was developed by Germany.

European Rendezvous

UK space science has always been a relatively healthy area, although funding levels have declined since the 1970s. Scientific satellites are on the frontier of technology and have positive feedback into our industrial capabilities. ESA is proposing an increased science programme, but a national programme is still needed, as instruments are provided nationally, with ESA providing the spacecraft.

Microgravity will be the next commercial area after Earth observation. That is, it could be an important manufacturing activity in 30 years time. There is currently a great lack of enthusiasm in the UK for this subject. It is likely that initial ideas will be swamped by applications not thought of as yet. Again launch costs are a problem when carrying out experiments. The question here is, should the UK increase its stake in the programme in the hope that it becomes commercial in time?

On the question of participation in the infrastructure programmes it is important to understand why the UK wants to join in the Space Station work. The real objective here is to get access to the Space Station. About one third of the UK expenditure on Columbus should go into the Space Station proper, rather than the Polar Platform area. The station will give the ability to build, repair, refuel and modify satellites in orbit. If the UK doesn't have access to these facilities, then it will be at a disadvantage with respect to other commercial organisations and interests.

In the area of technology the UK was the leader in the 1960's and early 1970's. However, it has now fallen sadly behind the rest of Europe. The UK programme has been the same in cash terms for more than a decade. That is, when the effects of inflation are taken into account there has been a large decrease in the money spent on technology.

Finally, Dr. Roberts discussed the whole area of launch vehicles. The UK abandoned its own launch vehicle programmes in the 1970's. In 1980 we finally joined the Ariane programme with Ariane 4, and may well take up a similar proportion, around 5 per cent of Ariane 5. It would be difficulty for the UK to contribute more, after being out of the business for so long. The UK is considering what proportion, if any, to take up on Hermes. There are already enough willing countries to do Hermes, without the UK participating.

ESA has recently decided to carry out a study programme for the next generation of launch vehicles, inc luding Hotol. It is too early to take any major decisions on Hotol, because it is at the proof of concept stage. No large funding or programmes are needed at present.

Launch costs are the key to economic, commercial systems. For a communications satellite, as an example, half of the system cost is in the launch. Hotol aims to reduce the cost to low Earth orbit by a factor of five, and the cost to geostationary orbit by two. Remote sensing systems use low orbits, and the launch costs would then be a small fraction of the system costs leading to better commercial prospects.

The Space Plan does not call for any decisions in this area, as none are needed at present but such a development in the future could put the UK and Europe way ahead of the competition in one stride. However, for the UK to be able to participate in such ventures the national technology capabilities, expertise and skills must be revitalised, and this is what the Space Plan is intended to achieve.

INTERNATIONAL SPACE REPORT

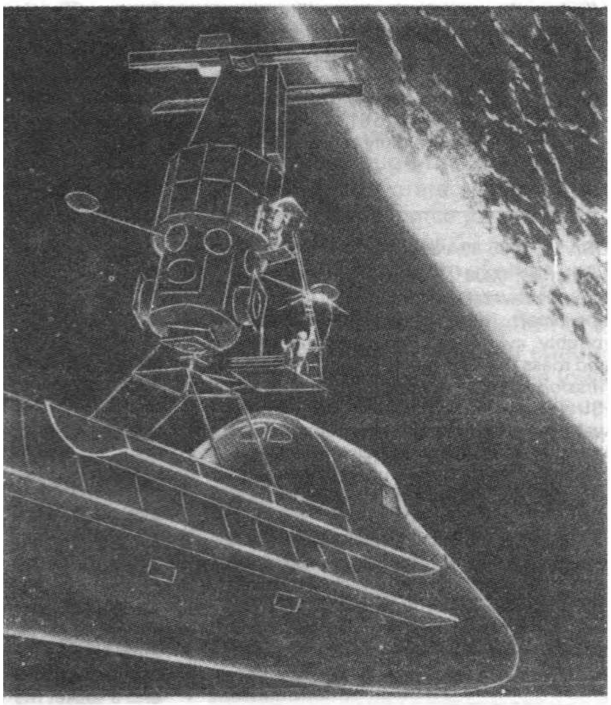
US PAYLOAD FOR CHINA

Pan Am Pacific Satellite Corporation has signed a formal agreement for a launch by China of its communications satellite before May 1988, thus becoming the second former Space Shuttle customer to contract for use of the Long March rocket.

The launch also will mark the first time a used satellite is returned to orbit. Pan Am Pacific bought the Westar 6 satellite that went into a faulty low Earth orbit after launch from a Shuttle in 1984 and was retrieved by another Shuttle later in the year. The firm paid $20 million to buy the satellite from insurance underwriters. Such a satellite, when new, costs between $60 million and $65 million with a booster rocket needed to propel it to the geostationary orbit.

No booster will be needed with the Long March rocket.

Western Union is the other US firm to have signed with the Chinese for a satellite launch.



An artist's concept of an outer space satellite service system that could repair or refurbish orbiting spacecraft, or prepare them for return to Earth. Lockheed Missiles and Space Co. is studying the concept under a contract from the US Air Force Space Division, supported by the Strategic Defense Initiative Organisation and NASA.

SATELLITE DIGEST – 198

Robert D. Christy

Continued from the December 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1775, 1986-66A, 16926.
Launched: 0800, 3 September 1986 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 348 x 414 km, 92.21 min, 70.37 deg.

COSMOS 1776, 1986-67A, 16928.
Launched: 0902, 3 September from Plesetsk, by C-1
Spacecraft data: Probably a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. The mass may be around 700 kg.
Mission: Probably electronic intelligence gathering.
Orbit: 474 x 516, 94.56 min, 74.03 deg.

MOLNIYA-1 (68), 1986-68A, 16934.
Launched: 0913, 5 September 1986 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.

Scout Puts 'Polar Bear' in Orbit

A $13 million scientific satellite left hanging in the National Air and Space Museum in Washington, D.C., for eight years was successfully launched on November 13 from Vandenberg Air Force Base in California.

The Polar Beacon Experiment and Auroral Research satellite – dubbed Polar Bar – was launched by a Scout rocket, which is one of NASA's smallest launch vehicles and has been launched more than 100 times since 1965 with a success rate of more than 90 per cent.

The 275-pound satellite carried three experiments designed to help communications and weather satellites avoid interference caused by the aurora borealis, also known as the Northern Lights. The lights cause spectacular displays of colour in far northern skies and also distort radio signals being sent to and from orbiting satellites. The experiments are designed to determine which radio frequencies can be used to avoid distortion created by the aurora.

The satellite was on display at the museum from 1976 to 1984. Only one solar cell out of thousands within the satellite was rated marginal and had to be replaced. The satellite was refurbished at Johns Hopkins Applied Physics Laboratory, where researchers installed the instrumentation needed to carry out the experiments. Using the old satellite rather than building a new one saved the Air Force about $2 million. An additional $6 to $8 million was saved by using spare parts to build the Scout rocket.

In return for the Polar Bear satellite, the museum received a Transit 5A satellite.

Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system within the USSR.
Orbit: Initially 638 x 40547, 734.68 min, 62.88 deg, then lowered to 613 x 39722 km, 717.74 min to ensure daily repeats of the ground track.

USA 19, 1986-69A & B, 16937 & 16938.
Launched: 0308*, 5 September 1986 from Cape Canaveral by Delta 3920.
Spacecraft data: Irregularly shaped, roughly cylindrical body – dimensions and mass not available.
Mission: Test of several elements of SDI (Strategic Defense Initiative) hardware. As well as making observations of a ground launched missile and its own upper stage, the main payload was used to intercept and destory by impact that same rocket stage.
Orbit: Initially 220 x 222 km, 88.6 min, 28.5 deg, then by way of manoeuvres to collide with the rocket stage which produced debris in the following orbits: 211 x 747 km, 94.05 min, 39.07 deg (payload) and 219 x 611 km, 92.66 min, 22.79 deg (rocket).

COSMOS 1777, 1986-70A, 16952.
Launched: 0149, 9 September 1986 from Plesetsk by C-1.
Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 776 x 813 km, 100.81 min, 74.01 deg.

COSMOS 1778-1780, 1986-71A-C, 16961-16963.
Launched: 1139, 16 September 1986 from Tyuratam, probably by a version of the D vehicle.
Spacecraft data: not available.
Mission: Navigation satellites in GLONASS (the Global Navigation Satellite System).
Orbit: 19132 x 19142 km, 676.02 min, 64.80 deg.

COSMOS 1781, 1986-72A, 16966.
Launched: 0800, 17 September 1986 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 346 x 416 km, 92.20 min, 70.37 deg.

NOAA 10, 1986-73A, 16969
Launched: 1552, 17 September 1986 from Vandenberg AFB by Delta.
Spacecraft data: Irregularly shaped, roughly cylindrical body about 2m diameter and 3.7 m long with a single solar panbel at right angles to one end. The mass is around 1700 kg.
Mission: Operational meteorological satellite owned by the National Oceanographic and Atmospheric Administration. It also carries a SARSAT search and rescue package to monitor emergency radio distress frequencies.
Orbit: 808 x 826 km, 101.29 min, 98.75 deg.

COSMOS 1782, 1986-74A, 16986.
Launched: 1835, 30 September 1986 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1400 kg. Stabilisation may either by by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 636 x 663 km, 97.78 min, 82.54 deg.

NASA Studies Crew Escape Systems

A crew escape system will probably be added to NASA's fleet of Orbiters in the future. NASA officials are not sure whether a bail-out system could be ready for the Shuttle Discovery in time for the first post-Challenger flight, now scheduled for February 18, 1988.

The leading candidate is a system in which astronauts would hookup to small rockets that would blast through the Shuttle's side hatch and pull crew members out by lanyards. The 30-inch rockets would propel astronauts through the Orbiter's side hatch and boost them past the Shuttle's wings and vertical stabiliser. The rockets would then jettison away from the spacecraft and parachutes would carry crew members back to Earth. The system would be similar to one currently used in high technology military aircraft.

Other systems being reviewed are:

- An escape module capable of breaking away from the Orbiter in the event of an emergency.

- A simple bail-out hatch in the top of the Orbiter.

- Ejection seats propelled by small rockets.

- A pressurised tank that would be ejected from the Shuttle's payload bay and descend to Earth by parachute.

- An airline-like slide that would allow astronauts to escape through an opening in the belly of an Orbiter.

The issue of crew escape for the Shuttle was raised almost immediately after the Challenger accident. The only escape system any Shuttle ever had – ejection seats in Columbia – was removed.

In April, astronaut Henry Hartsfield told the presidential commission that investigated the Challenger accident that he "would like to see some sort of low altitude escape system . . . some ability to bail out of the vehicle."

The commission subsequently recommended that NASA "make all efforts to provide a crew escape system for use during controlled gliding flight."

The commission, headed by former Secretary of State William Rogers, said it is "crucial that the vehicle that will carry astronauts into orbit through this decade and the next incorporate systems that provide some chance for crew survival in emergencies."

In July 1986, a team of engineers at Johnson Space Center in Houston recommended installation of a bail-out system that would enable astronauts to escape during a low-altitude emergency. The group studied different bailout systems, but was unable to find one that would have provided an escape for the seven crew members killed in the Challenger explosion.

NASA believes the systems being studied could give astronauts a chance to survive an emergency during gliding flight.

Photoquiz

The photograph on page 18 shows Canada's Canadarm in the payload bay of the US Orbiter, but can you identify the particular part of the Earth viewed here from orbit? *Clue:* The location is in the northern hemisphere and the view is towards the south. *Answer:* see page 37.

Hermes Mission to Mir Space Station

The possibility of a space link-up between the Hermes mini-shuttle and the Mir Space Station is being investigated.

Hermes, the French proposal now being evaluated by the European Space Agency (ESA) as a potential follow-on project to Ariane 5, could become the first non-Soviet spacecraft to dock with the country's space station in the mid to late 1990's.

Details of preliminary discussions for such a mission were revealed after the Soviet-French conference in Yerevan at the end of last year which met to sum up 20 years of cooperation between the two countries.

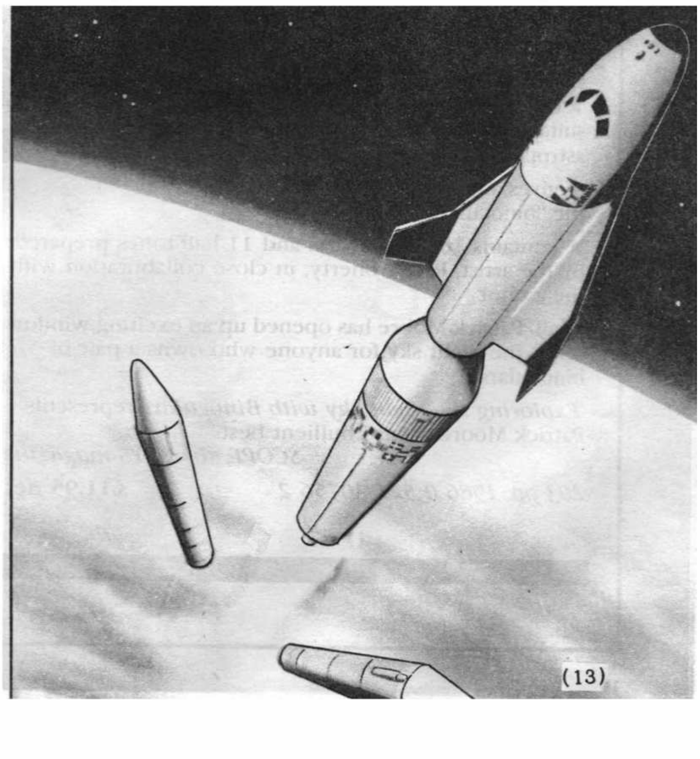
The conference also saw the signing of formal agreements for the joint space flight between the two countries next year.

French cosmonauts Jean-Loup Chretien and Michel Tognini have now begun formal training for a mission to the Mir Space Station in 1988.

One of them will spend a month on the station and, together with a Soviet cosmonaut, undertake an EVA. The flight will be much more ambitious than the mission accomplished by Chretien in 1982, hence the long training schedule.

Medical and biological experiments will be central to the mission and will follow on to those carried out during the first flight of a French cosmonaut.

Solid booster separation during an Ariane 5 launch to put the Hermes mini-shuttle into orbit. One possible mission now being discussed is a rendezvous with the Mir Space Station. *Aerospatiale*



SOVIET SCENE

PHOBOS EXPERIMENTS

Testing of the Phobos interplanetary probe, built to study Mars, its satellite Phobos, outer space and the Sun has begun. It will be launched in July 1988, taking about 200 days to reach its destination.

Part of the mission involves a unique, in-depth radar probing of the surface of Phobos. It will be "sounded" from a distance of less than 100 metres, the process taking just 15 minutes.

The soil will be examined by radar, layer by layer, to a depth of 2.5 km. This will hopefully yield valuable information on rock structure, density and the degree of rock homogeneity on electrical properties of the matter and, indirectly, on its chemical composition.

V. Balebanov, deputy Directory of the Space Research, Institute of the USSR Academy of Sciences, said: "Using special instruments, the two probes will thoroughly study the planet's surface, its atmosphere, ionosphere and magnetosphere. In January 1989 they will send back to Earth TV pictures of the planet, data about the chemical and mineralogical composition of the local rocks and their radiophysical characteristics. These data will be used to compile a thermal map of the planet Mars. We expect to unveil the secret of Martian dust storms.

"After that, the probes will be manoeuvred to join an elliptical orbit on Phobos. They will study the surface of the satellite from an altitude of 30 to 50 metres. In April 1989, they will drop long-term automatic stations onto its surface. They will probe the satellite with long-wave radiation, laser and ion beams to get information about the element and isotope composition of the satellite's mysterious soil."

In the picture opposite artist ***Peter G. Goodwin*** depicts a possible configuration of the 'Phobos landing craft during its descent. *© P.G. Goodwin.*

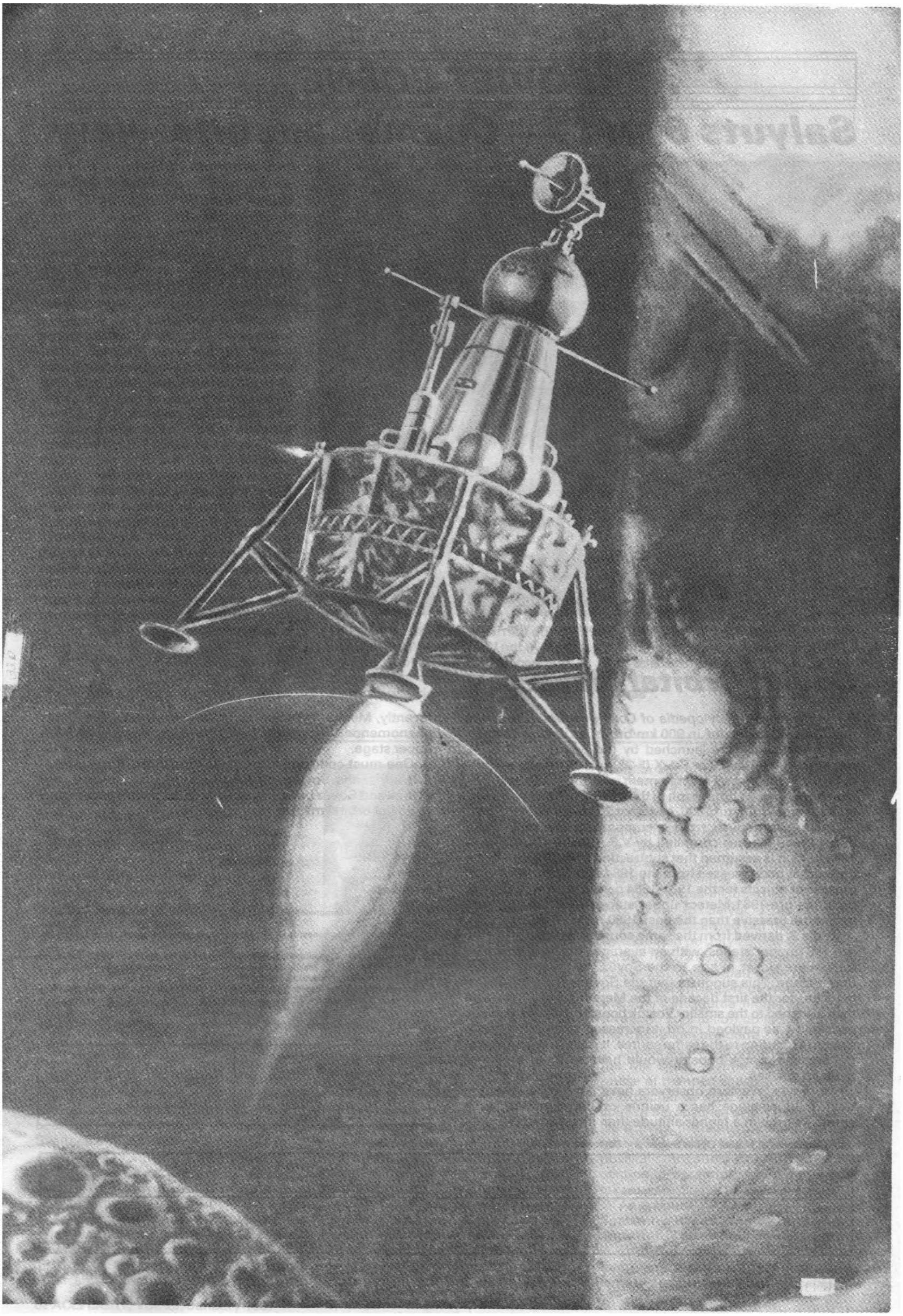
INTERGALACTIC ATMOSPHERE

Scientists at the Kharkov Institute of Radio Astronomy have discovered an "atmosphere" around our galaxy and the Andromeda Nebula. They believe that this space phenomenon is confined in a layer of rarefied ionised hydrogen at a very high temperatuare.

This may indicate the existence of a gas "bridge" between the two galaxies, through which hydrogen flows from our galaxy to the Nebula due to the latter's stronger gravitional field.

TUNGUSKA FERTILIZER

Research in the area of the Tunguska meteorite's fall has led to the development of a fertilizer which could help increase agricultural production by 50 per cent. The fertilizer includes all the elements of the meteorite – selenium, bromine, arsenic, mercury, lead, zinc, silver and other metals.



SOVIET SCENE

Salyuts 6 and 7 – Cosmonaut Interview

Viktor Savinykh (background) during a training session with Vladimir Kovalyonok for the Soyuz T-4 mission. *Novosti*

Cosmonaut Viktor Savinykh spoke to BIS member Bart Hendrickx recently about his 75 day mission aboard Salyut 6 in 1981 and a 168 day flight on Salyut 7 in 1985. The rare opportunity to meet and talk with a cosmonaut arose during a visit to Moscow by Mr. Hendrickx and he reports for *Spaceflight* below.

Savinykh confirmed that the prime objective of his Soyuz T-4/Salyut 6 mission with Vladimir Kovalyonok had been to receive the two remaining Interkosmos crews of the 1978 selection (involving Mongolian and Romanian cosmonauts). These were the last crews to fly the Soyuz-12 type two-man ferry. The Soyuz T-4 flight pattern had been entirely tailored to accommodate the visiting missions (Soyuz-39 and 40): the main crew were launched several days before the Mongolian launch window, then "waited" for the Romanian window to open about two months later (the Soviets strictly following their mysterious two month interval between visiting trips) and finally returned to Earth just a few days after Soyuz-40.

Soviet Orbital Masses

Sir, in the recent *Encylopedia of Cosmonautics,* it is stated that Meteor 2 satellites in 900 km orbits, as well as Meteor-Priroda satellites, are launched by the Soyuz booster (1), rather than the Vostok or F-1-X (F-2) booster, as is generally believed in the West. This statement is contradicted by Ref. 2, which contains a photograph of the Vostok booster rocket for Intercosmos-Bulgaria 1300, a Meteor 2 class satellite.

Table 1 is derived from a comparison of satellite and upper stage masses compiled by V.P. Glushko in 1980 and 1984 (3,4). It is assumed that subtraction of the 1980 satellite and rocket body masses from the 1984 data gives the orbital masses of objects for the 1981-1984 period. According to this data, the pre-1981 Meteor upper stages were, on the average, more massive than the post-1980 rocket bodies.

Table 2, derived from the same sources, indicates that the pre-1981 upper stages, with an average "dry" mass of 2.09 tons, were closer in size to the Soyuz, rather than Vostok, upper stage. This suggests that the Soviets used the Soyuz launcher for the first decade of the Meteor programme, and then switched to the smaller Vostok booster. This is a dubious possibility, as payload in orbit increased at the time of the switch, according to the same source. It is unlikely that use of the smaller Vostok booster would have resulted in higher payload masses.

Moreover, Western observers have determined that the Vostok upper stage has a unique orbital signature, as it enters its orbit in a higher altitude than its payload (5). Until recently, Meteor launcher upper stages have displayed this phenomenon, including the Intercosmos-Bulgaria 1300 upper stage.

One must conclude from the entries in the *Encylopedia* that either the Soviets no longer distinguish between the Vostok and Soyuz boosters, or that the Glushko's accounting of Soviet orbital masses may not be reliable.

DAVID ANDERMAN
California

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2. Mozjorin, Y.A. "Kosmonavtika CCCP" Mashinostroyeniye Publishers, Moscow 1986, pp. 442-443.
3. V.P. Glushko "The Development of Rocket Engines in the Soviet Union", 2nd Revised and Expanded Edition, Mashinostroyeniye Publishers, Moscow 1981, pp. 194-197.
4. V.P. Glushko "Kosmonavtika Entsiklopediya", p. 498.
5. Johnson, N.L. "The Soviet Year in Space – 1985", Teledyne Brown Engineering, Colorado Springs, 1986 p. 32.

Table 2: Average Orbital Stage "Dry" Masses by Launch Programme 1960-84 (metric tons).

Soyuz Class Orbital Stages Payload Type	Mass	*Vostok Class Upper Stages* Payload Type	Mass
Soyuz	2.36	Vostok	1.43
Soyuz T	2.29	Korable-Sputnik	1.39
Progress	2.30		

Table 1: Masses of Meteor Upper Stages and Payloads 1969-84 (metric tons).

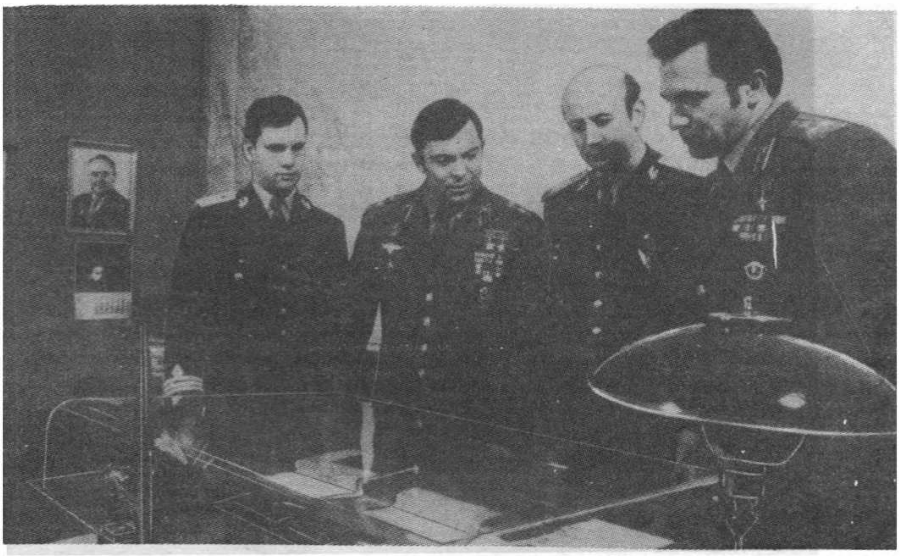
Launch Programme	Number	Total Mass in Orbit	Total Payload Mass	Average Payload Mass	Total Rocket Mass	Average Rocket Mass
Meteor (1969-80)	36	120.72	45.40	1.26	75.32	2.09
Meteor (1981-84)	6	17.10	8.20	2.09	8.90	1.48
Total Launches	42	137.82	53.60	1.28	84.22	2.01

SOVIET SCENE

Operationally, the two visiting flights were useless, since both crews had only been trained to fly the old Soyuz model and consequently could not perform an on-orbit swap of Soyuz T-4. Apparently, the Russians were reluctant to delay these two remaining missions of the old Soyuz to Salyut-7 as this would have required keeping the old Soyuz simulators and other related hardware operational for an additional year and postponing other scheduled visits to Salyut-7. They preferred instead to send up a final two-man Russian host crew to Salyut-6 to look after the Mongolian and Romanian guest cosmonauts.

The only other critical aim of this bonus mission was the installation of a special adaptor on one of Salyut's two docking ports (probably the front one) to make the unit compatible for the Cosmos 1267 module, which docked with Salyut-6 about a month after the Soyuz-4 landing. Asked why Cosmos 1267 coasted in low orbit for one month before gaining altitude to meet Salyut-6, Savinykh said this was done to test the vehicle's response to air drag. He did not explain why the module's return capsule was ejected at the end of that one month period in low orbit.

Concerning his 1985 Salyut-7 mission, Savinykh confirmed that the Soyuz T-14 Chegets crew would have stayed in orbit well beyond the New Year period if it had not been for commander Vasyutin's illness. Vasyutin had suffered from a "cold".



The two-man Soyuz-40 crew of Dumitru Prunariu (Romania) and Leonid Popov visit the Korolev Museum. Soyuz-40 was the final mission of the original Soyuz series.

The spacewalks performed by Kizim and Solovyov from Salyut-7 in May 1986 were to have been carried out by Savinykh and Vasyutin and not by Vasyutin and Volkov as some observers believed. The truss structure for the two EVAs was delivered to Salyut-7 by the Cosmos 1686 module in October 1985.

Savinykh was still undergoing regular medical examinations one year after his second mission ended in November 1985 and was not yet training for a new flight. About ten female cosmonauts were currently preparing for space missions at Zvyozdnyy Gorodok, among which were two "Irinas".

All-Woman Crew

Bart Hendrickx's report above of the training of 10 female cosmonauts confirms a similar report of late 1984 that was attributed to Svetlana Savitskaya, who has twice been in space (***Spaceflight*** 1985, p. 327). The object of the training was to prepare an all-woman crew for a future space station mission. It was expected that the mission would be of short duration with Svetlana Savitskaya as the commander.

The Soviet Space Programme can claim many firsts, particularly in the area of manned space flight, and on past evidence a high priority can be expected to be given to obtaining yet more.

To date, two Soviet women cosmonauts have been in space, both of them with firsts to their credit. Valentina Tereshkova was the first woman in space aboard Vostok 6 in February 1962 and held the distinction of having been the only woman in space until Svetlana's flight aboard Soyuz T-7 in August 1982.

The absence of women in space during the 20 years, 1962-82, was undoubtedly influenced by NASA's reluctance over many years to consider women astronauts and to continue to select military pilots. Finally in 1976, NASA encouraged women applicants and in January 1978 six women were selected as astronaut mission specialists.

Svetlana Savitskava during her EVA.

In March 1982, NASA announced its intention to fly its first woman astronaut, Sally Ride, the following year. By then NASA plans had already sparked a new Soviet initiative with women cosmonauts and Svetlana Savitskaya was included in a three person crew just five months later. It was also in 1982 that a further possible six women cosmonauts were selected to bring the total complement up to 10.

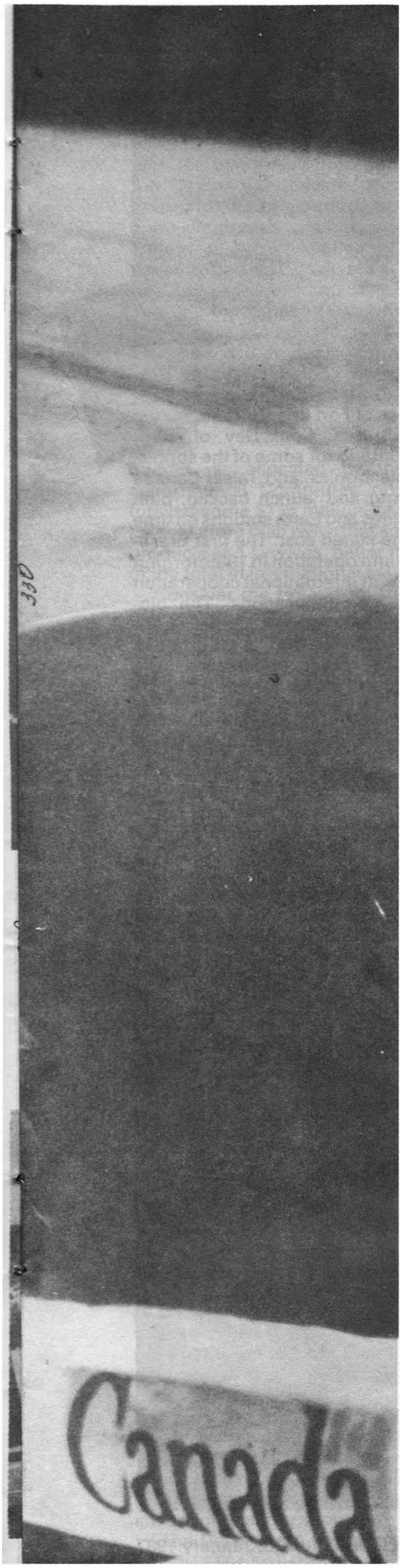
By mid-1984, NASA had flown four women in space and announced that Kathy Sullivan would do an EVA during the Space Shuttle mission 41-G in October of that year. Unfortunately, she did not achieve a first as Svetlana Savitskava was included in the Soyuz T-12 crew to Salyut 7 as a flight engineer and carried out the first EVA by a woman on July 25, 1984.

By 1985, the complement of US female astronauts had risen to 13 and the regular inclusion of women crew members in Shuttle flights seemed a foregone conclusion up to the time of the Challenger accident.

On the Soviet side, the launching of the Mir space station heralds a new phase of manned space activity which is expected to start in early 1987. In spite of the absence of any comparable US activity, the launch of an all-woman crew still needs to be taken as a serious possibility for some stage of the forthcoming programme when regard is taken of the Soviet appetite for firsts.

An account of 'American Women in Space' by Roger Wheeler and Philip Snowdon is due for publication shortly in *JBIS* (Journal of the British Interplanetary Society), whose contents are regularly listed in ***Spaceflight***.

Space Prowess Largely Unheralded But ...



Canada's Space Industry Thrives

Canada's space programme is fulfilling a critically important role on the international scene, being supported by an active and viable aerospace industry. Major Canadian projects relate to communications, the Canadarm and the Space Station. But Canada's space prowess has been largely unheralded, being overshadowed by that of its southerly neighbour. Recognition has come in the form of contracts to its space industry which can justifiably claim high standards in advanced technology. *Christopher G. Trump outlines the scope of Canada's space commitment in terms of present and future projects.**

Communications

September 1982, and a light plane flying over the wilderness of British Columbia struggles for altitude as its occupants search for another downed aircraft. But it is too late. The under-carriage clips the tops of tall pines and the plane settles down at a steep angle, its occupants miraculously unhurt. But they are lost to the world with a non-functioning radio. Fortunately an emergency locator transmitter (ELT) goes into action, its signal picked up by a Soviet weather satellite, which relays the data to a central Canadian Earth station. Within hours the downed aircraft is spotted and the world's first rescue via SARSAT – the Search and Rescue Satellite programme – is effected.

A downed Canadian plane spotted by a Soviet satellite! There is a symbolism in this historic premier that highlights the best that the space age has to offer mankind: Technology forged by many nations – in the case of SARSAT the United States, Soviet Union, France and Canada – for the benefit of all. To date SARSAT has been instrumental in saving hundreds of lives. In one recent case a seaman adrift in a life jacket in the Pacific has his ELT signal picked up by three satellites within one hour – a critical factor given that his chances of survival in the shark-infested waters were finite, at best.

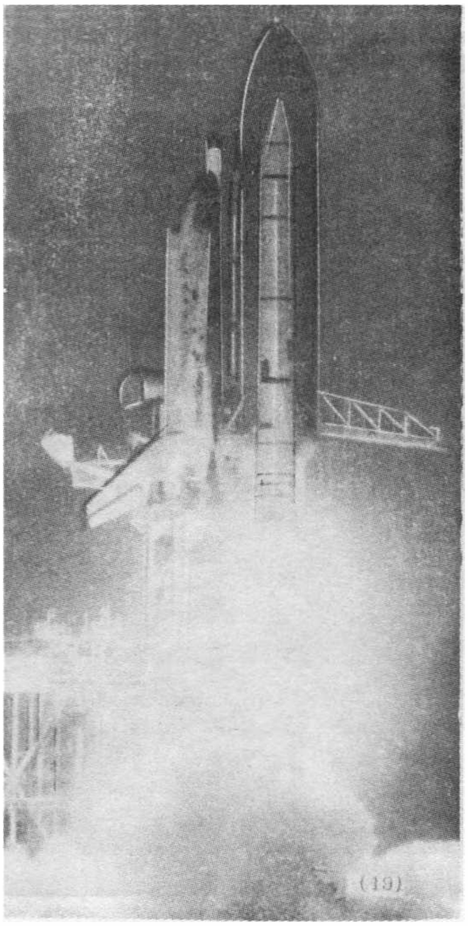
Communications has always been a critical factor in Canadian history – a nation of some 10 million square kilometres with the lowest population density in the world. It was no accident that the world's first commercial radio station, XWA, went into service in Montreal in 1919. The space age promised a quantum leap in communications capability, witnessed by the first Canadian satellite in 1962 – the Alouette, which was a product of the Defence Research Laboratory for probing the ionosphere.

Development of Canadarm

One of the little known Canadian inventions aboard the Alouette was the STEM – the Storable Tubular Extendible Members – a unique antenna that folded flat but extended to some 30 metres to gather important data. No one was around in those days to christen it the Cantenna, so its role was relatively unsung. But NASA took note and used the STEM aboard all of its manned spacecraft, including the Apollo capsules that explored the Moon, as well as scientific satellites, such as the Orbiting Geophysical Observatory. It was in this slender beginning that we find the genesis of the Canadarm, perhaps the best advertised example ever of Canadian technology.

After Apollo, NASA was intent on making the next phase of its space programme – the Space Transportation System – visibly international. Based on the STEM experience, Canada was a natural contender for

Launch of Anik C by the Space Shuttle.



**Vice President and Executive Assistant to the Chairman, Spar Aerospace Limited.*

this role. Spar Aerospace Limited, the maker of the STEM, was approached, but it remained for DSMA-Acton, a Toronto-based engineering firm to initiate the Canadian involvement. The company made a stubby robot arm to fuel the CANDU nuclear reactors. Engineers at NASA quickly juxtaposed it as a mission-critical component for the Space Shuttle – the crane or Shuttle Remote Manipulator System (SRMS) – to do useful work in space. A partnership of Spar, DSMA-Aton and CAE in Montreal presented a proposal to NASA, which in turn offered the following deal: If the Canadian companies would design, develop and give to NASA the first SRMS, then NASA would commit to buy others for future Shuttles... if it worked.

It was a deal of sorts, but at some $100 million investment, clearly beyond the capacity of private companies. In a classic case of government-industry cooperation, the National Research Council of Canada was given the assignment to spearhead the project. Farsighted parliamentarians – notably the present Governor General of Canada, Jeanne Sauvé, who at the time was Minister of Science and Technology – saw the effort as complementary to Canada's objectives in space. In 1974 the agreements were signed between Canada and the United States, because each nation saw its interests served by cooperating in a major adventure in space – the US to make more practical and palatable its space budget to Congress: Canada as a means of displaying its technological prowess in a global arena. It also meant new developments here on Earth, such as the world's largest remote manipulator – capable of moving more than a ton with an accuracy of 3 mm – to retube the Candu nuclear reactors; or research in making safer and more productive deep Earth mining.

It is in space that Canadarm has paid handsome dividends. The flawless performance of the Canadarm on its first test in the fall of 1981 reaped a new awareness of Canada's role in space that had been largely unheralded up to that time.

Canada's Space Role

How many are aware that Canada had placed into service the world's first domestic communications satellite in geostationary orbit in 1972? The communications network based on this feat, as accomplished by Telesat Canada, linked Canadians as they had never been before. For the first time telephone calls could be made as easily from Halifax to Inuvik as across town; the same evening's news could be seen simultaneously in Toronto as far to the north in Resolute Bay. At an altitude of 36,000 kilometres, due south of Regina and directly over the equator, the Anik A (the satellite's named derived from the Inuit word for brother) made short shrift of the great distances that had for so long isolated many Canadians.

The late Dr. John H. Chapman, often called the father of the Canadian space programme because of his pioneering work on the Alouette, had a vision for Canadian space communications that developed into an elegant three-point strategy:

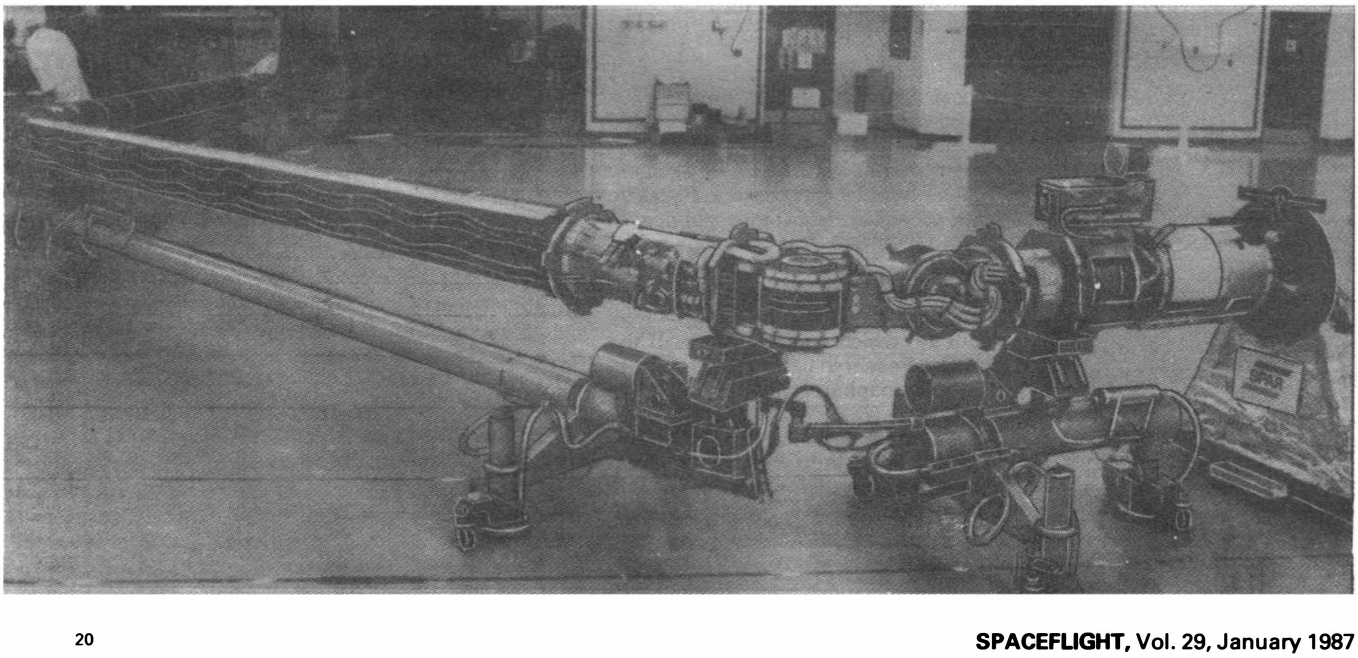
1. Space was a natural arena to meet the nation's communications needs.
2. this being the case, then Canada should also build for space
3. and its industry should be so competitive that it could sell in the international market place.

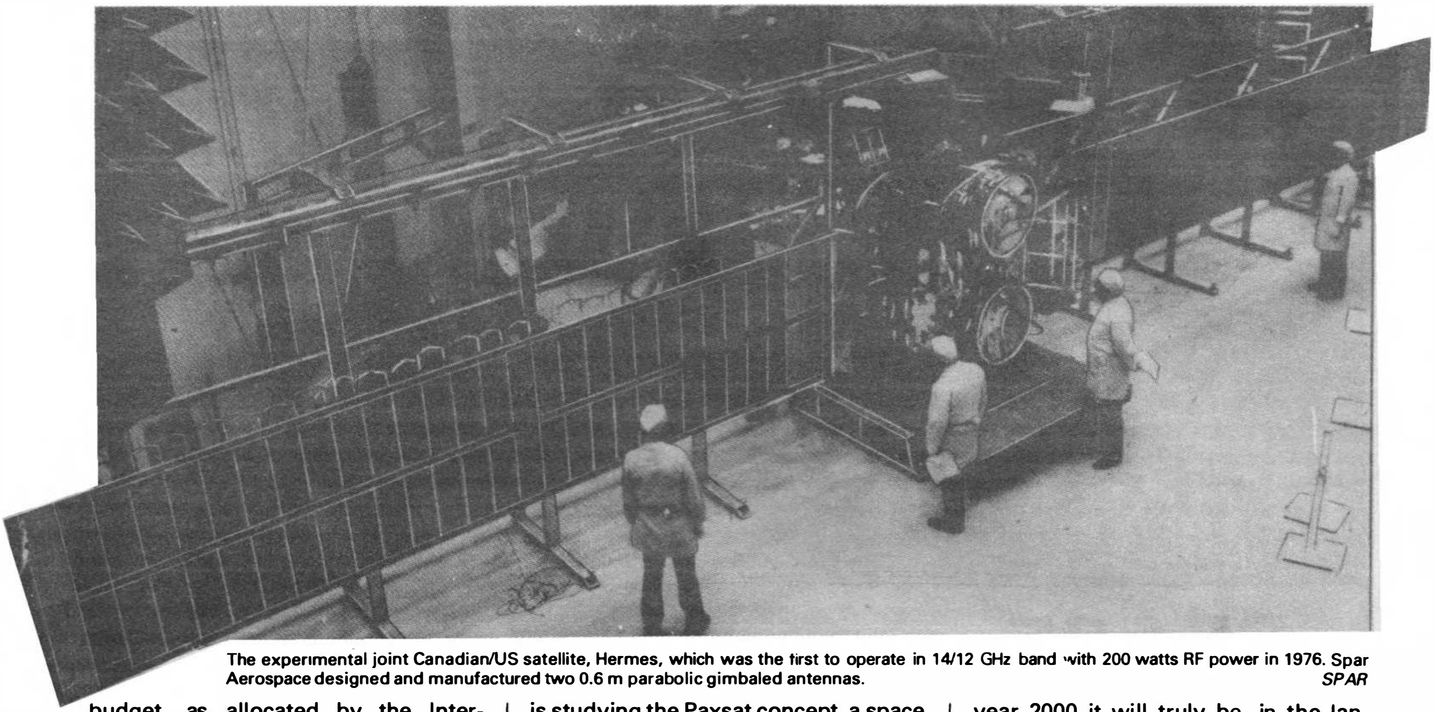
The Anik A, launched in 1972, had been built by Hughes Aircraft of California, with some 13 per cent Canadian industrial participation. But by 1982, Canadian industry had not only built its own satellite – the Anik D – but signed the contracts to build the first domestic satellite communications system in Latin America, a project known as Brasilsat. The performance of the Canadarm a year earlier had graphically underscored our technological capability. A team of Canadian industries, led by Spar and including SED of Saskatoon, Saskatchewan, for the Earth stations: Fleet Aerospace of Fort Erie, Ontario, for the spacecraft bus, Com Dev of Cambridge, Ontario for some of the sophisticated electronics, and Telsar Canada for training and launch backup, built the satellites and Earth stations on time and at the stated cost. The first Brasilsat went into operation in 1985, forging a new link in international cooperation in space communications. The pinpoint accuracy of the launch from French Guiana by a European Arianspace rocket underscored the dimensions of global participation.

Canadian Space Industry

The Canadian space industry, numbering perhaps a dozen companies, is largely owned by Canadian shareholders and has achieved results far out of proportion to its numerical strength – some 3,000 employees all told. Fiercely competitive in meeting Canadian needs, it has scored international sales that stand as a beacon for all Canadian industry. In 1983 the Canadian space

The remote manipulator system for NASA's shuttles on test at Spar Aerospace's special lab located in Toronto. SPAR





The experimental joint Canadian/US satellite, Hermes, which was the first to operate in 14/12 GHz band with 200 watts RF power in 1976. Spar Aerospace designed and manufactured two 0.6 m parabolic gimbaled antennas. *SPAR*

budget, as allocated by the Interdepartmental Committee on Space, totalled some $135 million. The industry sold more than twice that amount in products and services, better than half of the total in international sales.

Consider the breadth of the Canadian effort. Bristol Aerospace of Winnipeg builds one of the world's finest sounding rockets – the Black Brant used to study the upper atmosphere; Canadian Astronautics Limited of Ottawa is working on a space probe to study the invisible plasma of space – the Waves in Space Programme, while MDA of Richmond, British Columbia is a world leader in remote sensing imagery, the awesome photography from space that will help us to better understand the geography, geology and flora of our Earth.

The Future

The Department of Communications is exploring with industry particpants the M-sat concept – a mobile satellite system in the high fraequency range that will make possible direct satellite links to the remotest areas. Before the turn of the century it may be possible for users to talk by way of these satellites from vehicles, ships and on foot with Earth stations no larger than a briefcase.

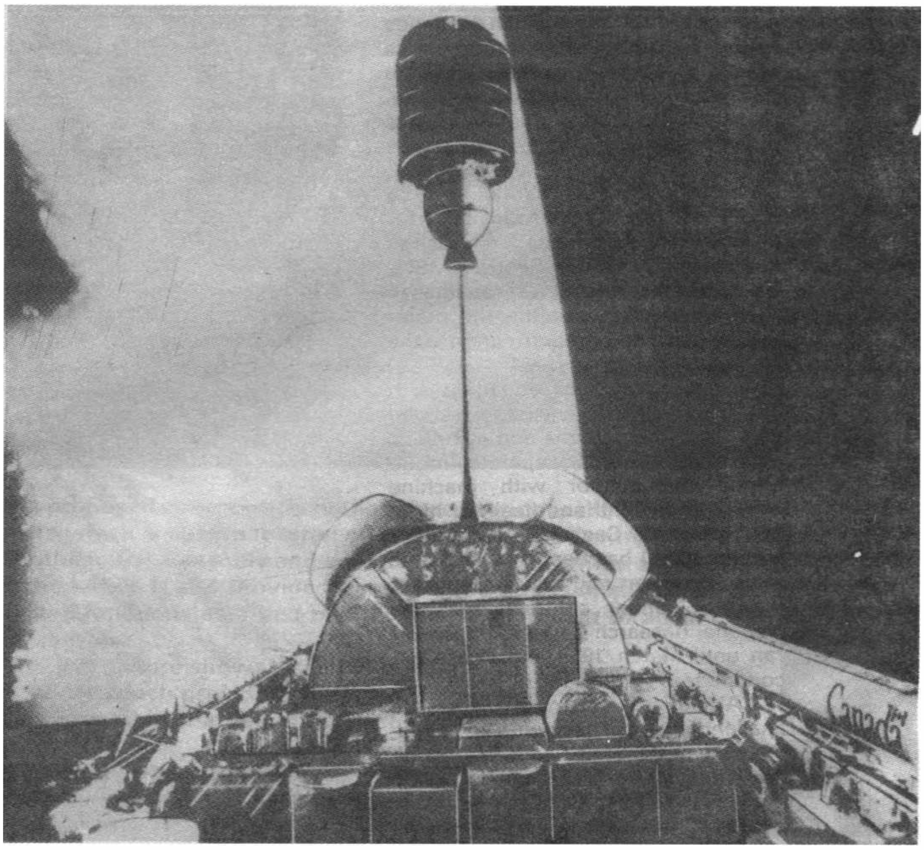
The Department of Energy, Mines and Resources is working with the private sector on Radarsat, a remote sensing satellite that will – in the nineties – make daily sweeps over the Arctic, ferreting out the best shipping channels with its ability to spot weak or firm, old or new ice. The technology is so advanced that the potential yield of a province's entire potato crop can be assessed in one sweep. Think of the global impact of such data in giving early warning of droughts and incipient famines.

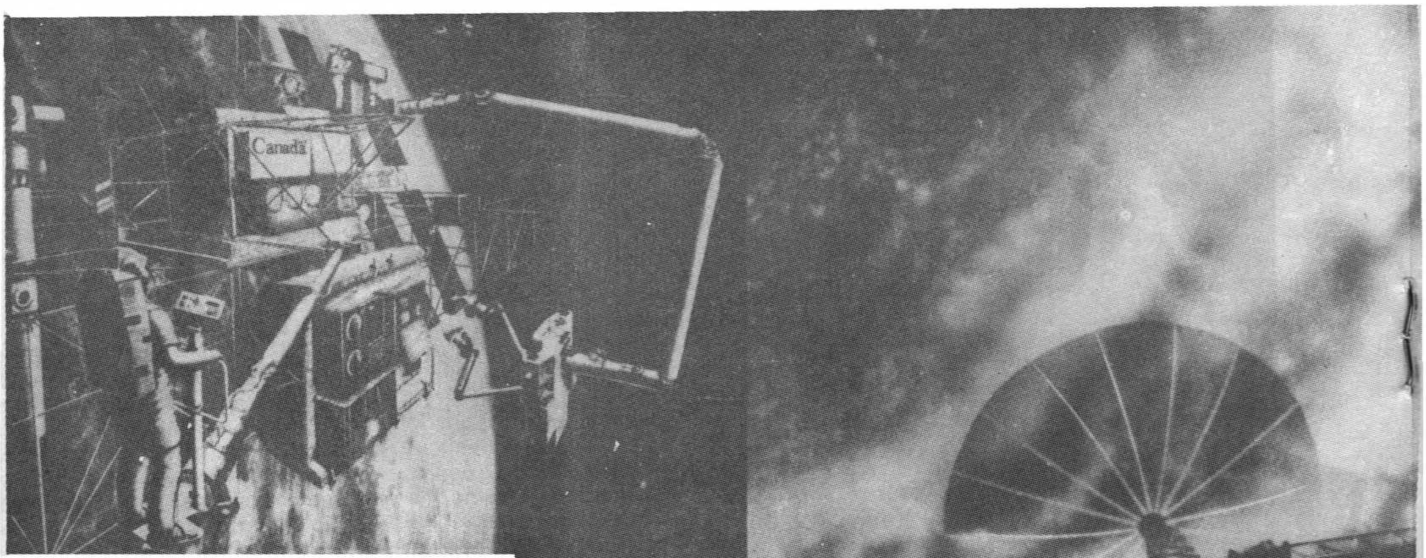
The Department of Defense has initiated studies for a space-based radar surveillance net to ensure the sovereignty of our shores.

The Department of External Affairs is studying the Paxsat concept, a space watchdog satellite capable of determining intentions of other satellites, for use in the event that the nations of the world should ever agree on the concept of banning not only weapons of mass destruction but all weapons from space.

Then there is the grandest project of them all: Space Station. Canada has joined with European nations and Japan in cooperating with the United States in the construction and utilisation of a permanently manned platform in space. Once in place before the year 2000 it will truly be, in the language of the Ojibway, a Pi-Wapic – an iron star visible even by day. Research undertaken in the Space Station will give us an expanded understanding of our Earth and the Universe; it will lead to new concepts in pharmaceutical manufacturing, metallurgy, crystal growth and human physiology. Most importantly, it will lead to a fresh outlook of our role as stewards to this spaceship Earth – a single small, inhabited planet among nine in our Solar System; itself but an infinitesmal speck in our Milky Way Galaxy.

Canada's Anik C satellite launched as part of the first commercial payload of the Space Shuttle. *SPAR*





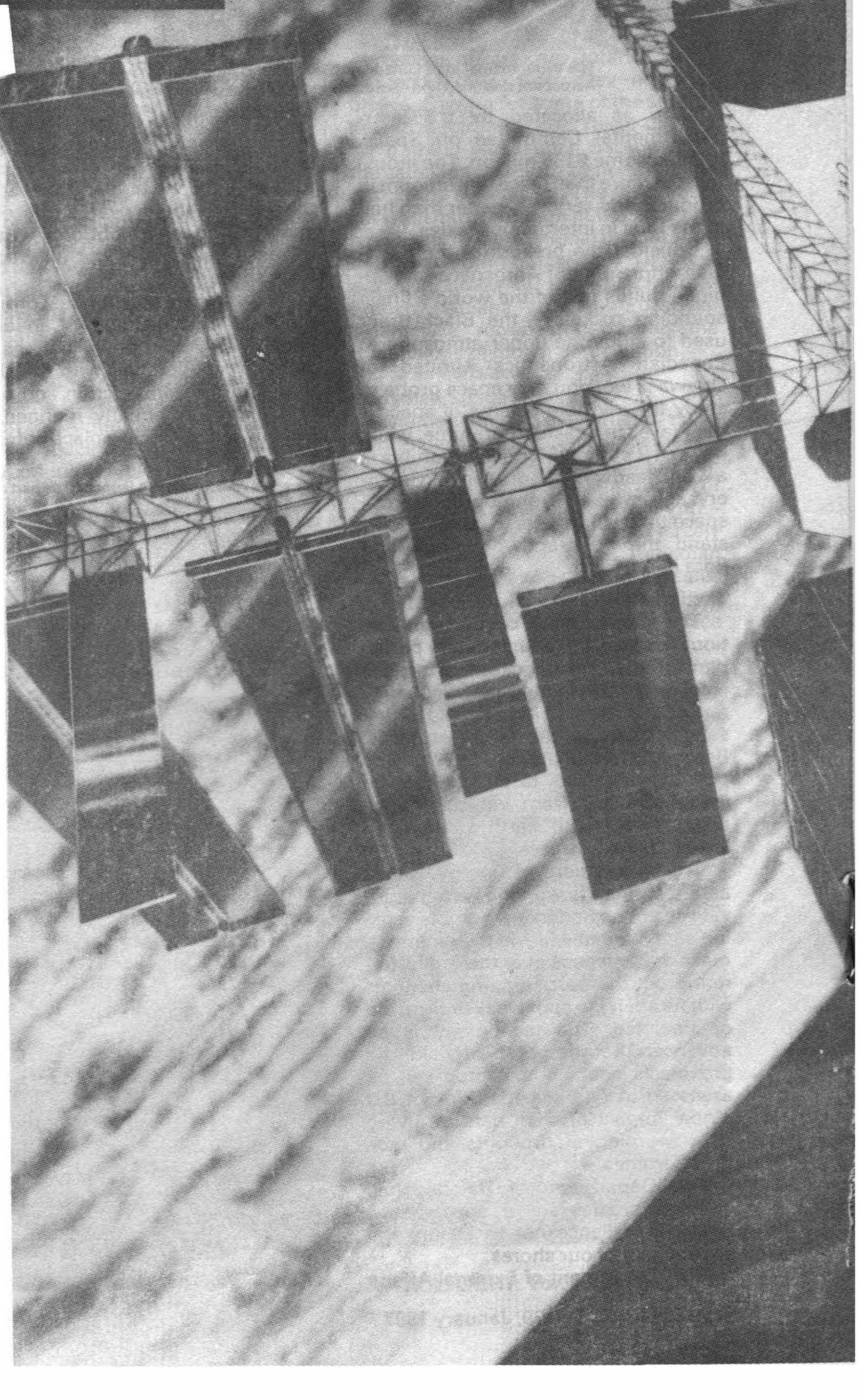
SPACE STATION PARTNER

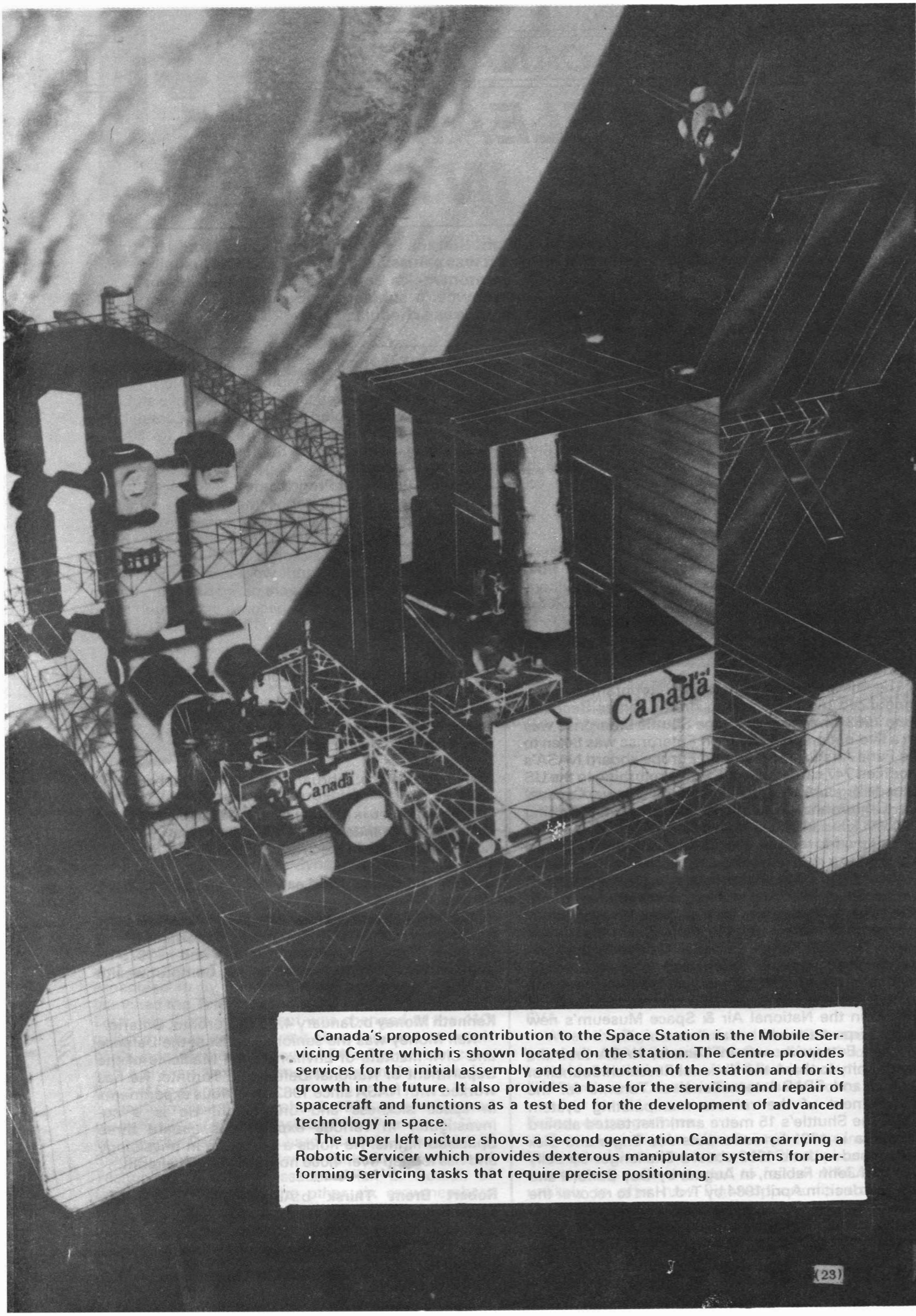
The US Space Station, which will begin to be assembled in orbit after 1992, will draw on international co-operation from Japan, Canada and the European Space Agency (ESA).

Participation in the Space Station is widely backed in Canada. The Canadian Institute for Advanced Research considers that the very nature of the project will create a large investment in new knowledge and pay rich dividends in the 21st Century. A report of its Space Station Committee looks to Canadian participation to "demonstrate and enlarge the capabilities of Canada's space industry, assisting it to expand employment and markets". Canadian participation should not be piecemeal, but take "responsibility for an integral part of the Station", such as a Mobile Servicing Centre (MSC), which will service and test satellites in space and could become the major Canadian hardware contribution to the station.

An MSC would be equipped with advanced robotics, including second generation Canadarms and a Robotic Servicer – a small, separate, multi-armed manipulator with machine senses and 'sight' and 'feel' for high-precision tasks. Canadian Astronautics Limited (CAL) has been working on a Phase B design and development for the MSC under contract from the National Research Council: Phase B-1 ran until March 1986 and Phase B-2 continues to August 1987.

CAL's Space Systems Group has the challenging job of designing and building power, computer and data-handling subsystems. These subsystems would then be available for use on all aspects of the space station including free-flying platforms.





Canada's proposed contribution to the Space Station is the Mobile Servicing Centre which is shown located on the station. The Centre provides services for the initial assembly and construction of the station and for its growth in the future. It also provides a base for the servicing and repair of spacecraft and functions as a test bed for the development of advanced technology in space.

The upper left picture shows a second generation Canadarm carrying a Robotic Servicer which provides dexterous manipulator systems for performing servicing tasks that require precise positioning.

CANADA
THE MAPLELEAF IN SPACE

by Philip Chien

Most early writers and space prophets thought that the first person into space would be an American and to the surprise of the world it was a Russian. Writers in the 50's (usually British writers), wrote about the first Commonwealth subject into space as being English, but, wrong again. The first Commonwealth subject to go into space was a Canadian. A second Canadian astronaut flight was scheduled for September 24, 1986 before the Challenger accident.

Introduction

In September 1982 the crew for the first Spacelab mission was selected and included Ulf Merbold of West Germany. He became the first non-American to fly the Shuttle as a payload specialist aboard the first Spacelab flight (November 1983). As a representative of the European Space Agency (ESA) his first flight paved the way for future international space co-operation.

NASA needed a crew of five astronauts for most missions, but there were seven seats available. These extra seats were reserved for industry experimenters, but could also be available for observers from countries or companies which launch major payloads from the Shuttle. Since Columbia had only enough room for four NASA crewpersons, the plan was temporarily put on hold; but as Challenger and Discovery came online, plans were formulated to add observers to Shuttle crews.

The new "guest astronaut" programme was announced by NASA administrator James Beggs in June 1983 when the prototype Shuttle Enterprise was on a five-nation publicity tour. Enterprise was taken to the Paris Airshow and around Europe aboard NASA's modified 747 carrier aircraft. While returning to the US it made a good-will publicity stop in Ottawa, Canada. The Orbiter and 747 Biplane combination, weighing 223,600 kilos (483,000 lb), was one of the heaviest aircraft ever to land at Ottawa International Airport as it braked to a dust-throwing stop in front of thousands of cheering tourists and local people. The two aircraft were seen by over two million people on the month-long two continent tour.

Enterprise was returned to its hangar at the Dryden Space Flight Research Center in California after the tour finished and was then used to check out the Vandenberg Air Force Base launch facilities. It will not go into space, however, and is expected to eventually end up in the National Air & Space Museum's new Dulles Airport annex.

While Enterprise was in Canada, NASA took the opportunity to thank the National Research Council of Canada and SPAR International of Toronto for the development of the remote manipulating system (RMS, the Shuttle's 15 metre arm) first tested aboard Columbia in 1981 by astronauts Joe Engle and Dick Truly, used in June 1983 aboard Challenger by Sally Ride and John Fabian, in August by Guy Bulford and Dale Gardner, in April 1984 by T. J. Hart to recover the Solar Max research satellite, in November by Anna Fischer to help recover the two HS-376 satellites, and on many other flights. Most Shuttle flights involve some use of the RMS. It has launched satellites, retrieved satellites, steadied astronauts, moved experiments, and even tapped the cover of a stubborn cannister which would not open. The Canadarm is expected to play a major role in setting up NASA's permanent manned Space Station

Canadian Astronaut Programme

After the official announcement of the Canadian astronaut programme, advertisements were placed in Canadian newspapers and journals. Over 4,000 Canadians applied for a chance to fly into space. 1,600 met the educational and work-related experience qualifications, and these were pared down to 19 from which six were chosen to become astronauts, being introduced on December 5, 1983 to the Canadian public and the world. They are:

Roberta Lynn Bondar b: December 4, 1948, Sault Ste. Marie, Ontario.

Dr. Bondar is a neurologist and a clinical and basic science researcher in neuro-ophthalmology. She is also a licenced doctor and pilot.

Marc Garneau b:February 23, 1949, Quebec City, Quebec.

Marc Garneau is a career Naval officer and holds the rank of Commander in the Canadian Navy. He also holds a doctorate in Electrical Engineering.

Steven Glenwood MacLean b:December 14, 1954, Ottawa, Ontario.

Steven MacLean is a laser physicist with a doctorate in astrophysics. In 1976-77 he was a member of the Canadian National Gymnastics Team and in 1978 he appeared in TV commercials for the Commonwealth Games.

Kenneth Money b:January 4, 1935, Toronto, Ontario.

Ken Money was the senior scientist at the Defence and Civil Institute of Environmental Medicine of the Department of National Defence in Toronto. He has worked with NASA since 1962 on various experiments in space sickness and orientation. He is a co-investigator in various experiments aboard three Spacelab flights. He holds a doctorate in physiology and has logged over 4,000 hours in various aircraft.

Robert Brent Thirsk b:August 17, 1953, New Westminster, B.C.

Bob Thirsk is a medical doctor, who also has a masters degree in mechanical engineering from MIT.

The Canadian Space Team. Left to right are payload specialists: Ken Money, Bob Thirsk, Roberta Bondar, Steve MacLean, Bjarni Tryggvason and Marc Garneau. The team became operational in 1984. The only member to have flown in space is Marc Garneau aboard STS 41G in October 1984. Following the Challenger accident, no statements have yet been made about future crew assignments and the inclusion of guest astronauts from other countries is unlikely until the resumed launch programme has become established.

Bjarni V. Tryggvason b:September 21, 1945, Reykjavick, Iceland.

Bjarni Tryggvason holds a doctorate in engineering with specialisation in applied mathematics and aero-dynamics. He is an aero-dynamics researcher and meteorologist.

Marc Garneau

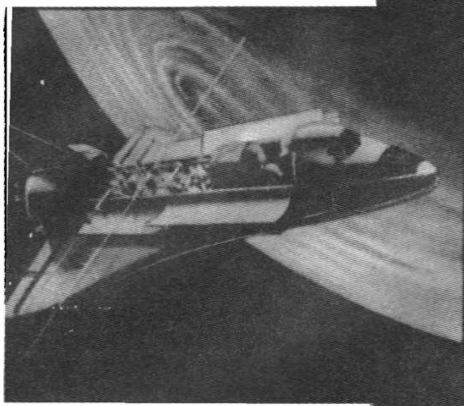
Marc Garneau was selected as prime payload specialist for the October 1984 flight and Bob Thirsk was selected as his backup. Originally Garneau was scheduled to fly aboard Shuttle mission 51A which launched the Telesat-H (Anik D1) satellite for Canada. Later, his flight assignment was changed to the 41G mission, which would permit observations over much of Canada. Garneau joined NASA's five person crew and a civilian Navy Oceanographer on the eight-day flight of Challenger.

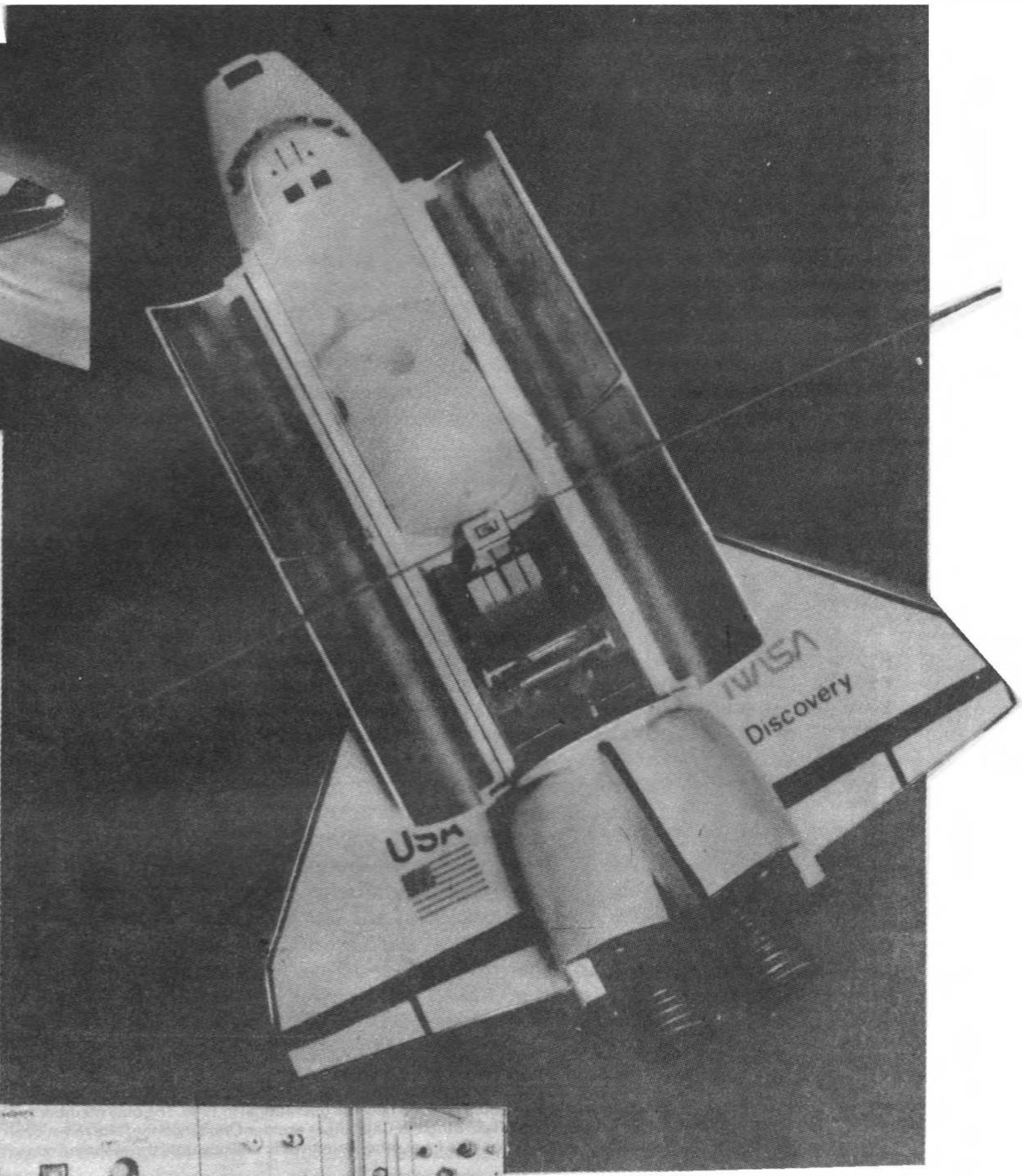
On the morning of October 5, 1984, everything was ready for launch. VIPs included the Premier of New Brunswick, Canada, Richard Hatfield, Thomas E. Siddon, Canada's Minister of State for Science and Technology, and Ambassador Allan E. Gotlieb of Canada. Garneau and the other six crewmembers were launched into a high inclination (57 degree) orbit, designed for viewing most of the populated parts of the Earth, including most of Canada. Marc Garneau's CANEX experiments covered space technology, space science, and life sciences. The space technology experiments included research into enhancements for the next generation robot arm for use in space. In the space science field, observations were made on how the Shuttle's space environment affected various substances used on the outside of the Shuttle. The life science studies concentrated on various motion sickness tests and sensory tests. While Garneau worked on his experiments, Paul Scully-Power observed the Earth's oceans from space and Kathy Sullivan became the first American woman to do an EVA.

When the flight was finished Marc Garneau made a goodwill tour of Canada. The Canadian public came to meet him in their thousands. Most just wanted to say "Hi!" and meet Canada's first ambassador to space.

Follow-on programme

Two more flights with Canadian astronauts had been scheduled at the time of the Shuttle accident and many more were expected to follow. NASA is now unlikely to offer new flight opportunities to guest astronauts from other countries until well after Shuttle flights have resumed in 1988.

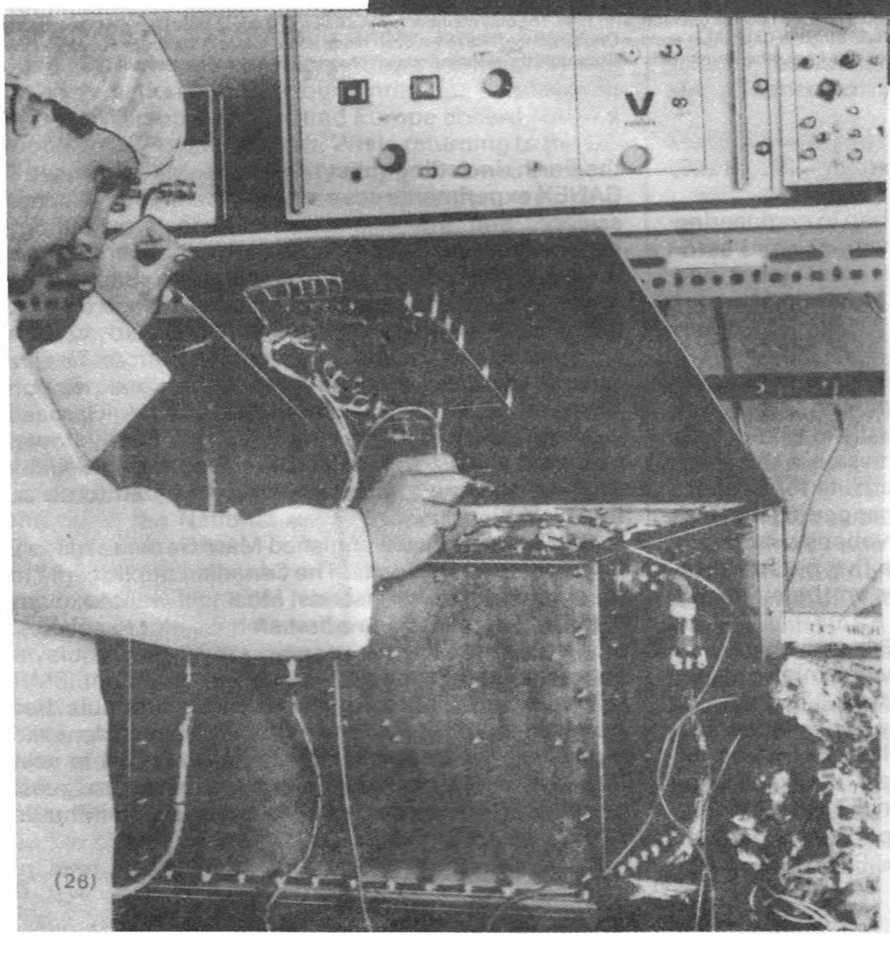




Above and right: A joint Canada-US experiment to be flown on the US Shuttle in 1991 is the WISP (Waves in Space Plasma) experiment, which follows the tradition of earlier Canada-US ionospheric research on the Alouette and ISIS satellites.

Canadian Astronautics Limited is developing Canada's instrument, called the High Frequency Sounder System, which will transmit radio waves into the ionosphere through a 300 m dipole antenna. The reflected waves are detected by the HFSS receiver on the Shuttle. Transmit and receive frequency is independently variable from 0.1 to 30 MHz in 1 kHz steps. Overall control of the experiment is by a stored program which is adjusted by the Payload Specialist or by the scientist on the ground.

Below: The HFSS engineering model under development at CAL.
Below right: A computer graphics analysis of the performance of the WISP experiment.



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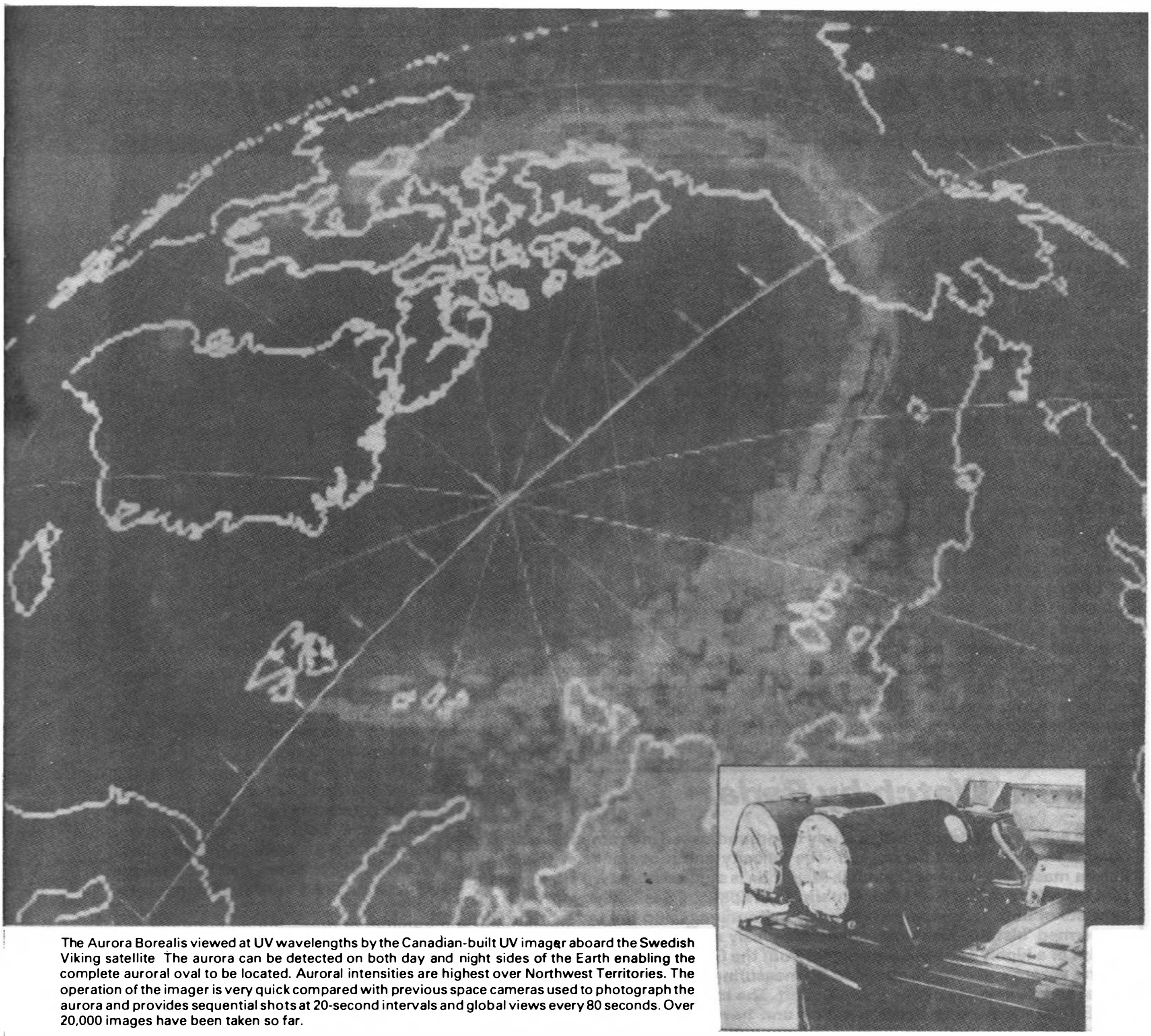
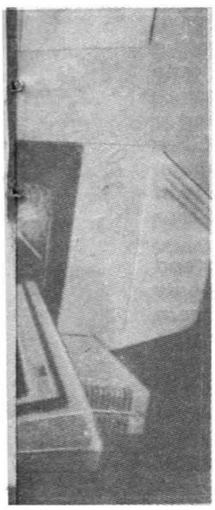


The Aurora Borealis viewed at UV wavelengths by the Canadian-built UV imager aboard the Swedish Viking satellite The aurora can be detected on both day and night sides of the Earth enabling the complete auroral oval to be located. Auroral intensities are highest over Northwest Territories. The operation of the imager is very quick compared with previous space cameras used to photograph the aurora and provides sequential shots at 20-second intervals and global views every 80 seconds. Over 20,000 images have been taken so far.

Explores Upper Atmosphere From Space



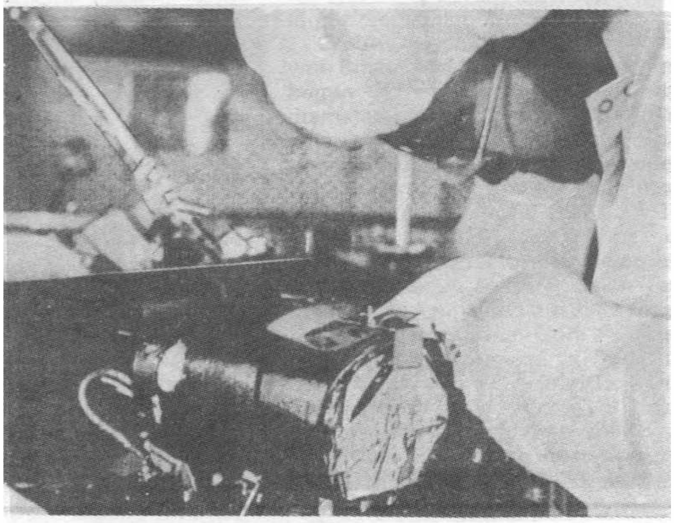
Sweden's first scientific satellite, Viking, launched by Ariane on February 22, 1986 together with the French remote sensing satellite Spot 1, has already exceeded its design life of eight months.

Viking built to study ionospheric and magnetospheric phenomena at high altitudes above the auroral zones, carried five main experiments one of which, the Ultra-Violet Imager, was supplied by Canada's National Research Council (NRC) as part of the country's space science programme.

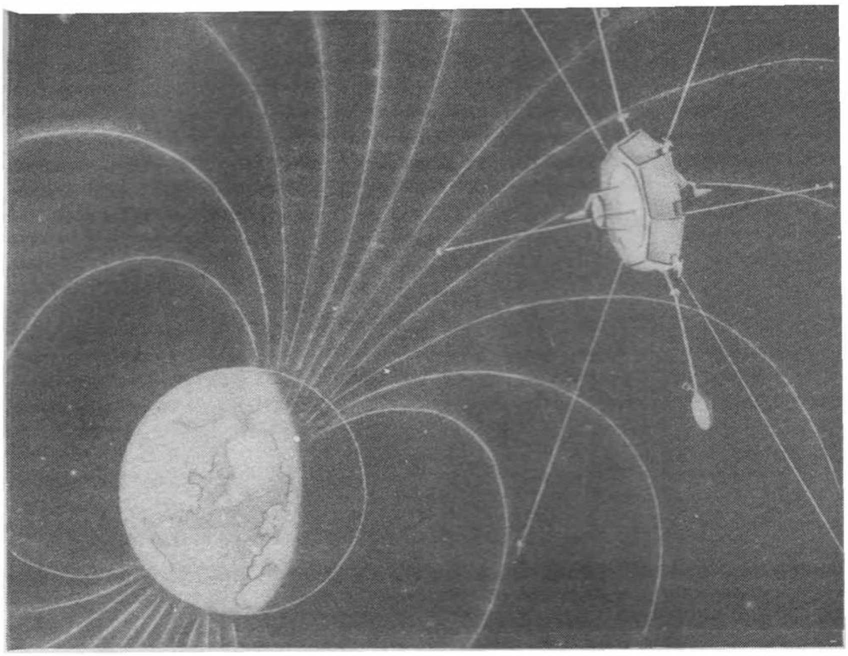
Developed by Canadian Astronautics Ltd., under contract to NRC, the instrument's two ultra-violet (UV) cameras have produced the most advanced satellite images ever taken of the aurora.

Further details overleaf.

Above and below: The UV spaceborne imaging system, developed for the Swedish Viking satellite, during laboratory checkout.



Aurora Watch From Orbit



Viking was designed to study ionospheric and magnetospheric phenomena at high altitudes above the auroral zones – such studies traditionally hold strong positions in Canadian and Swedish research, partly due to areas of both countries being situated within the northern auroral zone. It was thus quite natural that the first Swedish research satellite to be flown should aim at studying ionospheric and magnetospheric phenomena at high latitudes and that Canada should be interested in participating.

The region of the magnetosphere that Viking has been exploring is located roughly between 4000 and 15 000 km above the Earth's poles and is penetrated by magnetic field lines that lead down to the auroral zone.

It appears likely that the particles (electrons and protons) in the magnetosphere get heated and accelerated to high energies in this particular region. In order to investigate the mechanisms involved, Viking was fully instrumented for in situ measurements of the electric and magnetic fields including their frequency of disturbance. Simultaneously the Canadian Ultra-Violet Imager has been photographing the associated auroral activity taking place well below the spacecraft in the ionosphere over the north pole. As a result, the relationship between the processes at the satellite location and the auroral forms below can be investigated.

The Imager was developed and built by Canadian Astronautics Limited under contract to NRC's Canada Centre for Space Science. The instrument comprises two "state-of-the-art" ultraviolet (UV) cameras which produce the most advanced satellite images ever taken of the aurora. The UV Imager is capable of operating day or night and at higher speeds than any previous satellite imager. The key to the UV Imager's speed is a charge coupled device (CCD) integrated circuit chip containing over 60,000 individual light-sensing elements. The Imager at apogee is capable of transmitting one pair of images covering most of the auroral oval every 80 seconds. Smaller fields can be transmitted as frequently as every 20 seconds.

The launch by Ariane put Viking in a near polar circular orbit at approximately 800 km height. By means of a separate boost motor, Viking was injected into an orbit with the desired apogee of about 15 000 km and a perigee height of just over 800 km. The orbital period is just under five hours, out of which time, the satellite is at heights above 4000 km for close to four hours.

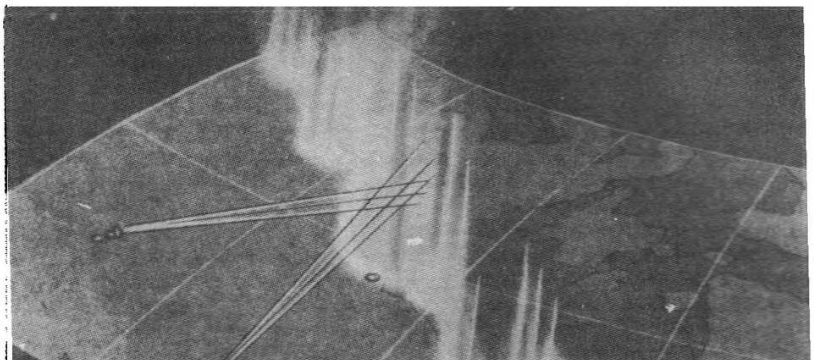
Acquisition of telemetry data and operation of the satellite experiments is undertaken at Kiruna in northern Sweden. Only real-time telemetry is available and the experiments operate only when the satellite is within view of Kiruna. After six months of operation 20,000 UV images have been taken and the UV Imager has been described as a complete success, performing up to expectations in every respect.

Aurora Watch by Radar

The aurora is under extensive study by ground-based instruments, including radar by which it may be tracked. The velocity and movement of the bright aurora mass centred over Churchill, Manitoba is studied from two sites equidistant from Churchill at Red Lake, Ontario and Nipawan, Saskatchewan. Each site consists of both receiving and transmitting antennas and the radars therefore are termed 'bistatic'. Each radar simultaneously sends pulses over Churchill on receipt of a highly accurate time signal from the GOES satellite.

The aurora's density is obtained by measuring the strength of the returned signal and its velocity by the Doppler shift. The radars form a system known as BARS (Bistatic Auroral Radar System) and have been supplied by Canadian Astronautics Limited. The system employs advanced, computer-controlled, digital beamforming which may be controlled remotely by experimenters throughout Canada over public telephone lines.

Used in conjunction with the Ultra-Violet Imager on the Viking Satellite, the data from BARS can be correlated with the satellite data to obtain a more complete picture of the auroral activity.



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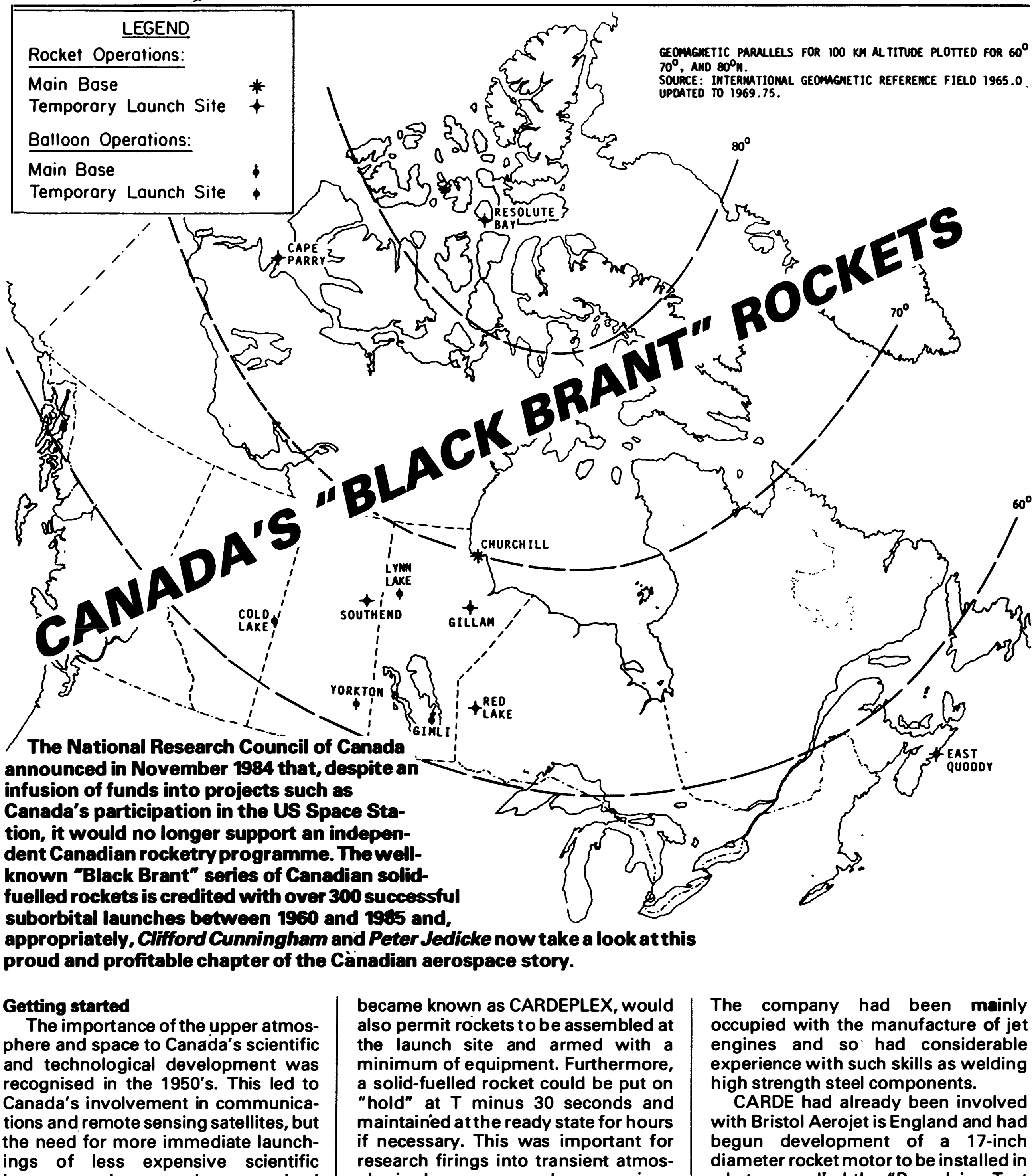


CANADA'S "BLACK BRANT" ROCKETS

The National Research Council of Canada announced in November 1984 that, despite an infusion of funds into projects such as Canada's participation in the US Space Station, it would no longer support an independent Canadian rocketry programme. The well-known "Black Brant" series of Canadian solid-fuelled rockets is credited with over 300 successful suborbital launches between 1960 and 1985 and, appropriately, *Clifford Cunningham* and *Peter Jedicke* now take a look at this proud and profitable chapter of the Canadian aerospace story.

Getting started

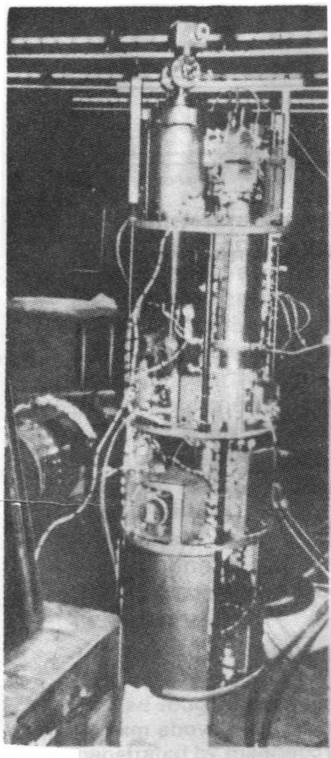
The importance of the upper atmosphere and space to Canada's scientific and technological development was recognised in the 1950's. This led to Canada's involvement in communications and remote sensing satellites, but the need for more immediate launchings of less expensive scientific instrumentation was also recognised [1].

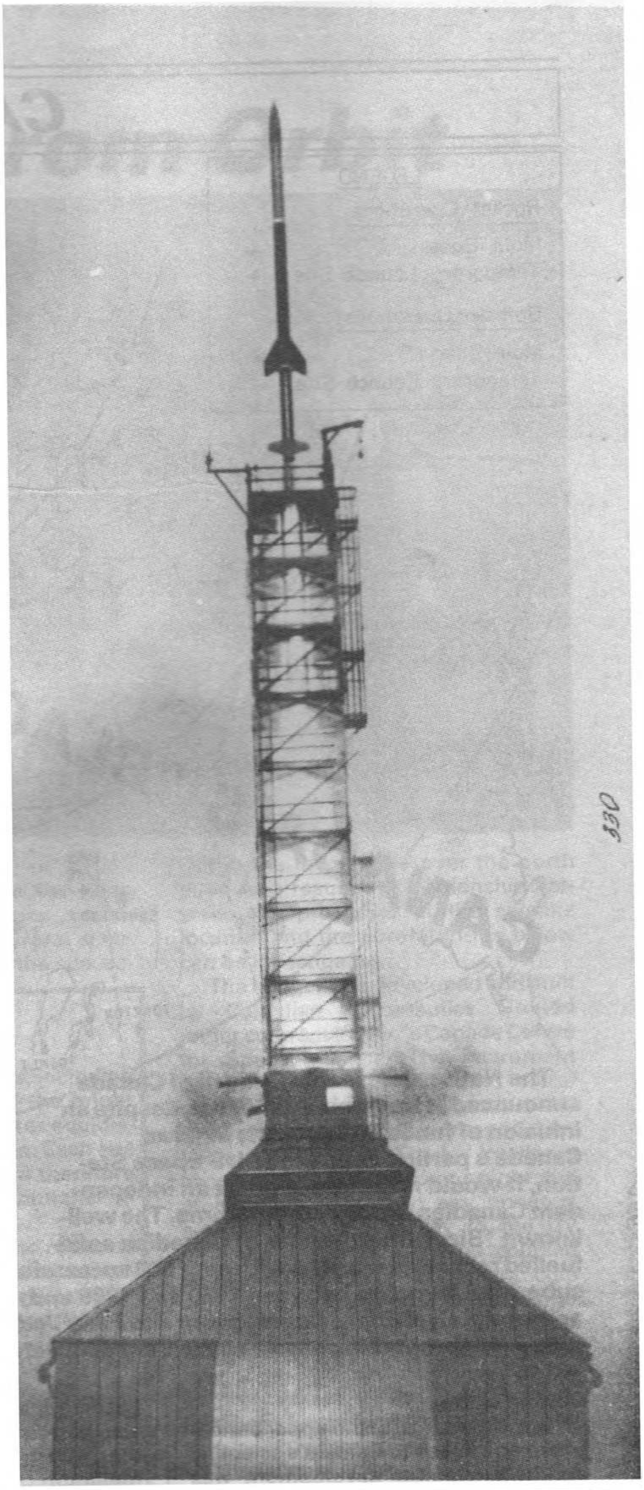
The direct impetus for a Canadian rocket programme came not from the scientists, however, but from the military. The Canadian Armament Research and Development Establishment (CRDE), located in Valcartier, Quebec, (which is today known as the Defense Research Establishment, Valcartier – DREV) wanted to develop a new solid rocket fuel in order to facilitate safe and simple transportation to remote locations. The fuel, which became known as CARDEPLEX, would also permit rockets to be assembled at the launch site and armed with a minimum of equipment. Furthermore, a solid-fuelled rocket could be put on "hold" at T minus 30 seconds and maintained at the ready state for hours if necessary. This was important for research firings into transient atmospheric phenomena, such as aurora.

Such research was planned by the Canadian military utilising facilities under development at the Churchill Research Range in Manitoba as the launch site. Churchill is located 985 km north of Winnipeg by air, and a railway connection also existed. The aurora belt is accessible from Churchill by suborbital rocket.

In Winnipeg, Bristol Aero-Industries Ltd (the Canadian branch of the British-based Bristol Aeroplane Company) wanted to join the aerospace field [2]. The company had been mainly occupied with the manufacture of jet engines and so had considerable experience with such skills as welding high strength steel components.

CARDE had already been involved with Bristol Aerojet is England and had begun development of a 17-inch diameter rocket motor to be installed in what was called the "Propulsion Test Vehicle," using CARDEPLEX propellant. The first static firing of this motor, 17 feet long, took place on February 24, 1959, generating 20,000 lbs of thrust[3]. As Bristol in Winnipeg grew into the project, the "Propulsion Test Vehicle" was renamed the Black Brant I, the name being taken from a species of goose indigenous to Western Canada. Firings of Black Brant I at Churchill, in cooperation with the US Army, demonstrated full fuel reliability. In 1959, CARDE upgraded the design and



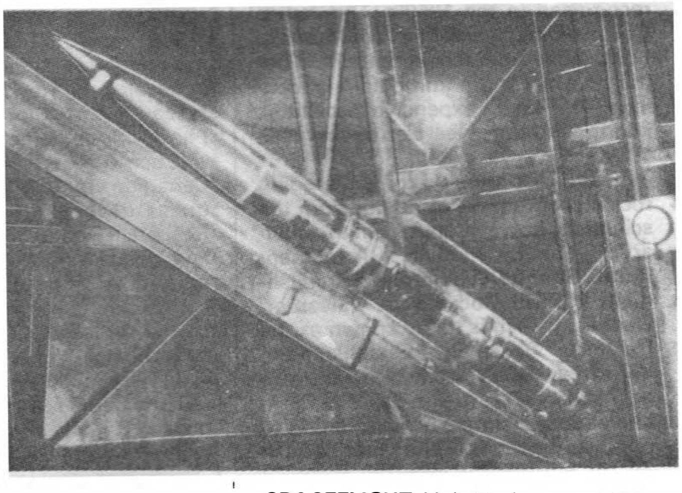


Left: The payload bay of the Black Brant VIIIC launched on May 27, 1985 for NASA auroral studies. The payload was recovered.

Right: Launch of a Black Brant VIIIC from the Churchill Research Range.

Lower Left: The first Black Brant X at the Wallops Flight Facility prior to the test flight on August 14, 1981. The sounding rocket has three stages and is 15.8 m long. *Bristol Aerospace*

Lower right: The forward section of the Black Brant XB launched on February 14, 1985 for the Science Project MARIE. The payload was not recovered.



created the Black Brant II, which could reach an altitude of 150 km. The first Black Brant II swept gracefully from the pad at Churchill in October 1960[4].

Bristol Aero-Industries

Complete engineering control of the programme was transferred to Bristol in 1961. Bristol had organised a Special Projects Group to co-ordinate their work with the Black Brant. This group has four divisions:

1. Propulsion–motor case, nozzle and igniter design.
2. Vehicle development-aerodynamics, structure, dynamics and performance of the complete rocket.
3. Instrumentation–diagnostic payloads to monitor flight behaviour.
4. Drafting group.

Later, a new division, responsible for field trials, was added. Meanwhile, the Canadian Government's National Research Council's Rocket Instrumentation Group did telemetry antenna design and payload components, and the NBRC's National Aeronautical Establishment's High-Speed Wind Tunnel Group also contributed aerodynamic research.

It is interesting to note that one of the challenges facing the engineers in the early years was to find materials in North America which were compatible with the British materials used in CARDE's early work.

Bristol then proposed the next three designs on its own initiative. The Black Brant III was 10 inches in diameter, weighed 700 lbs (of which 40 lbs was payload) and achieved 178 km altitude. The fuel used for this rocket was CARDEPLEX. Bristol built the motor case and CARDE filled it with fuel. This motor underwent 53 static firing tests before its first launch on June 15, 1962. Because of an unrelated fire, which had closed the entire rocket base at Churchill, the first Black Brant III launch took place at the NASA range on Wallops Island in Virgina. Four flights took place over the next few days. Although the launches proved the basic design, there were serious aerodynamic problems: the first three rockets pitched and achieved less than 80 per cent of their predicted altitude. The fins were canted on the fourth rocket before launch in order to spin the vehicle three times per second and stabilise it gyroscopically, but, although the pitching disturbance was cured, its flight was also unstable, flying off course in a helical path. Work to overcome this problem began immediately.

Bristol competed for a US Navy rocket contract while redisign was still in progress but the Balck Brant III was unsuccessful in competition. Additional data finally allowed the engineers to conclude that the Black Brant III needed to roll eight times per second – not three – in order to achieve stability.

Three Black Brant IIIs were successfully launched on February 21, 1966 with predicted altitude exceeded by 10 per cent. That particular design was called the Black Brant IIIA and 45 were sold and launched in the following years, the US Navy eventually becoming a satisfied customer. In the late 1960s, with a fuel more powerful than CARDEPLEX, a Black Brant IIIB was inaugurated. It featured 30 per cent better performance ratings and a total of 22 of them were launched.

Bristol also developed the ability to erect temporary launch complexes in remote locations. A Black Brant III was launched from Resolute Bay, Northwest Territories in July 1966 and the same site was used on nine subsequent occasions before 1971. With increased oil exploration activities in Canada's Arctic, it became very difficult to obtain a clear impact area for rocket firings. Facilities were also set up to launch four Black Brant IIIs from East Quoddy, Nova Scotia, during each of the 1970 and 1972 total solar eclipses.

A Two-Stage Design

The more ambitious Black Brant IV was a two-stage design, incorporating the Black Brant II (with the original motor design and original CARDEPLEX fuel) atop the Black Brant IIIA (a new motor and the original fuel). The stages were slip-fitted together, rather than firmly attached, with the intent that they would slip apart as the first booster stopped thrusting. The Churchill rocket range, rebuilt after the fire, was used for the first launch on June 24, 1964. However, the two stages collided after separation and crashed about three km from launch site. A second test on July 2, 1964 had the same disastrous result, but engineers received data showing that the staging had taken place about five seconds too early. They concluded that pressure building up between the two stages had pushed them apart too early. The engineers vented the interstage, and installed explosive bolts and flush-mounted booster drag flaps to extend at separation.

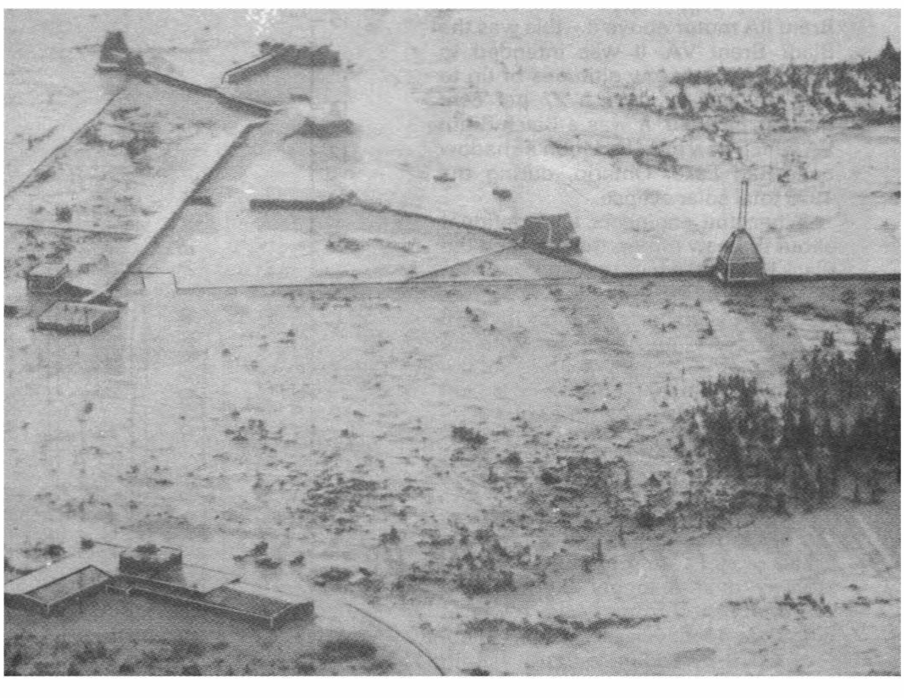
The third and fourth tests in January 1965 were totally successful, and the sixth test set a Canadian altitude record of 950 km. The combination of a Black Brant II and a Black Brant IIIA became known as a Black Brant IVA; while a Black Brant II with a Black Brant IIIB as its second stage was designated the Black Brant IVB. By May 1981, 59 Black Brant IVs in all had been flown from such far-flung sites a Peru, Spain, the Hawaiian Islands and Greenland.

Bristol Aerospace

During this exciting time of development, significant corporate developments also took place. In March 1962, a new company was formed, Canadian Bristol Aerojet Ltd., by Bristol Aero-Industries and the American company, Aerojet-General Corporation. The new organisation built the CDN$2 million Rockwood Propellant Plant, 30 km north of the city of Winnipeg. Then the Bristol conglomerate was acquired by Rolls Royce and renamed Bristol Aerospace Limited. The Special Projects Group in Winnipeg became the Rocket and Space Division in 1966.

By that time a completely new

Churchill Research Range Facility.



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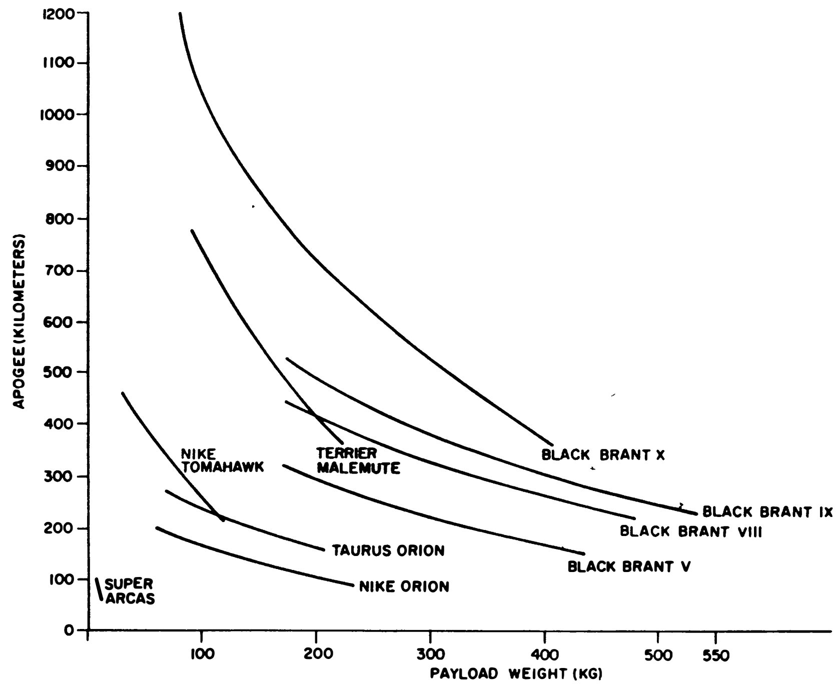


Sounding rocket performance.

design with more powerful solid fuel and a lighter structure was on the drawing boards. It utilised a new tail assembly with fins made of honeycomb aluminium, covered with a plastic insulator called "Avcoat" which kept the aluminium from melting due to friction during the ascent. Development of this new rocket was troubled by inadequate insulation inside the motor tube. Thirteen static firings were required to solve the problems, but the efforts culminated in the birth of the Black Brant V. At first, the new tail assembly was mated with a Black Brant IIA motor above it – this was the Black Brant VA. It was intended to reach relatively low altitudes of up to 150 km and to carry a 27 per cent heavier payload. It was a Black Brant VA which flew into the Moon's shadow over Red Lake, Ontario, during the 1979 total solar eclipse.

When the engineers felt confident about the new motor, they created the Black Brant VB which was successful in its very first test in June 1965. There were five such tests, ending in April 1967, and all were successful. With the Black Brant VB, the involvement of the Canadian military ended and Bristol carried the Black Brant programme on alone from that point.

Increased US Involvement

NASA played an important role in the Black Brant V's evolution when it asked Bristol to improve the rocket's stability over a longer flight profile when launched from a 50m tower at the White Sands Missile Range. Bristol responded by adding a fourth tail fin and calling the combination the Black Brant VC. This version became a stalwart in NASA's stable of sounding rockets. Between the three models, over 145 Black Brant Vs have flown.

Further development followed different paths. When, in 1967, the US Army wanted mass-produced rockets to launch meteorological packages that would descend on parachutes, Bristol offered a new Black Brant VI. It weighed a mere 50 kg with a seven kg payload and was intended to reach altitudes no greater than 90 km. An even smaller rocket, the Black Brant VII, was also developed: it weighed 18 kg, was only 10 cm in diameter and could carry 1.5 kg payloads up to 40 km. These designs used simple mechanical spring timers to eject the nose fairings and Bristol employed electron beam welding to attach the fins to the rocket bodies.

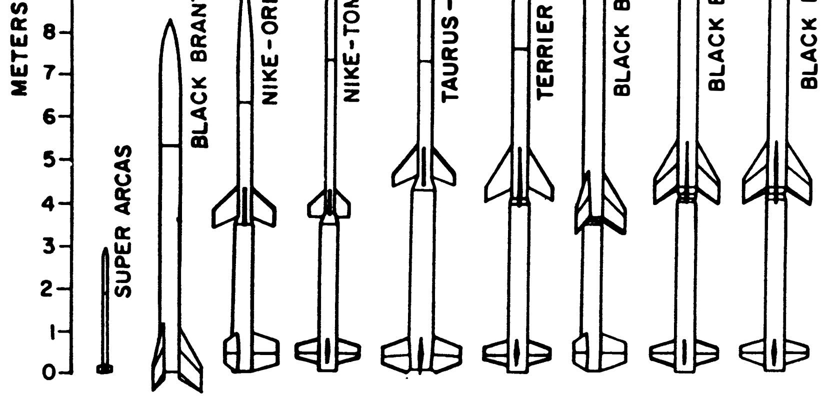
Initially, Bristol hoped to produce them in quantity for less than CDN$1,000, but the actual cost was consistently higher than this. There were 226 test firings of the Black Brant VI and 52 of the Black Brant VII; both met their performance requirements but could not achieve the high reliability at low cost and the US Army rejected them. The National Research Council of Canada has launched 15 Black Brant VIs over the years for low-altitude research.

Meanwhile, the concept of combining proven rocket elements was applied to create the Black Brant VIII, which used a US Army Nike booster and a Black Brant VB or VC as second stage. This increased peak altitude by 40 per cent over either previous design. The Black Brant VIII was test-fired in December 1975 and 41 were flown to 1980. A similar combination replaced the Nike with the US Navy Terrier booster, and this was designated as the Black Brant IX. Although NASA funded the design study at Bristol, it was not actually flight-rated until the successful firing of its successor, the Black Brant X.

A Three-Stage Design

The Black Brant X was initiated by

Sounding rockets launched at the CRR.



Bristol itself and was the company's first three-stage rocket. It consisted of a Terrier booster stage with a Black Brant VB as the second stage (thus making the first two stages essentially identical to the Black Brant IX; hence the peculiarity of having both versions flight-rated together). The third stage was based on the engine used in the Black Brant VB and VC, but with a shorter rocket case length and a new propellant. The new motor would have 12,000 lbs of thrust and a burn time of 17 seconds. Bristol named this rocket engine "Nihka", which means "Little Goose", and four static firings proved its worth[5].

For the Black Brant X's first test flight, NASA's Goddard Space Flight Centre supplied a Terrier booster and a diagnostic payload, and the National Research Council of Canada paid for the second stage. SAAB-Scania from Sweden provided a modified S-19 active trajectory control module. The first flight took place on August 14, 1981 at Wallops Island and was a resounding success. An interesting point about the Black Brant X's mission profile is that the second stage is left attached for 33.6 seconds after burning out. This is because the third stage is so short and squat that it would lack stability, and the second stage's fins keep it true. This delay means that separation finally occurs at 80 km altitude, where the atmosphere is so thin that the third stage remains stable with a spin of 3.6 times per second. The third stage then coasts alone for four seconds before firing.

It is the Black Brant X programme which is most at risk as a result of the Canadian government's decision to stop supporting rocketry. Recently, there have been calls in the United States for more expendable boosters in the wake of the Challenger disaster, but the Canadian government has not indicated renewed interest in Bristol's stable of rockets.

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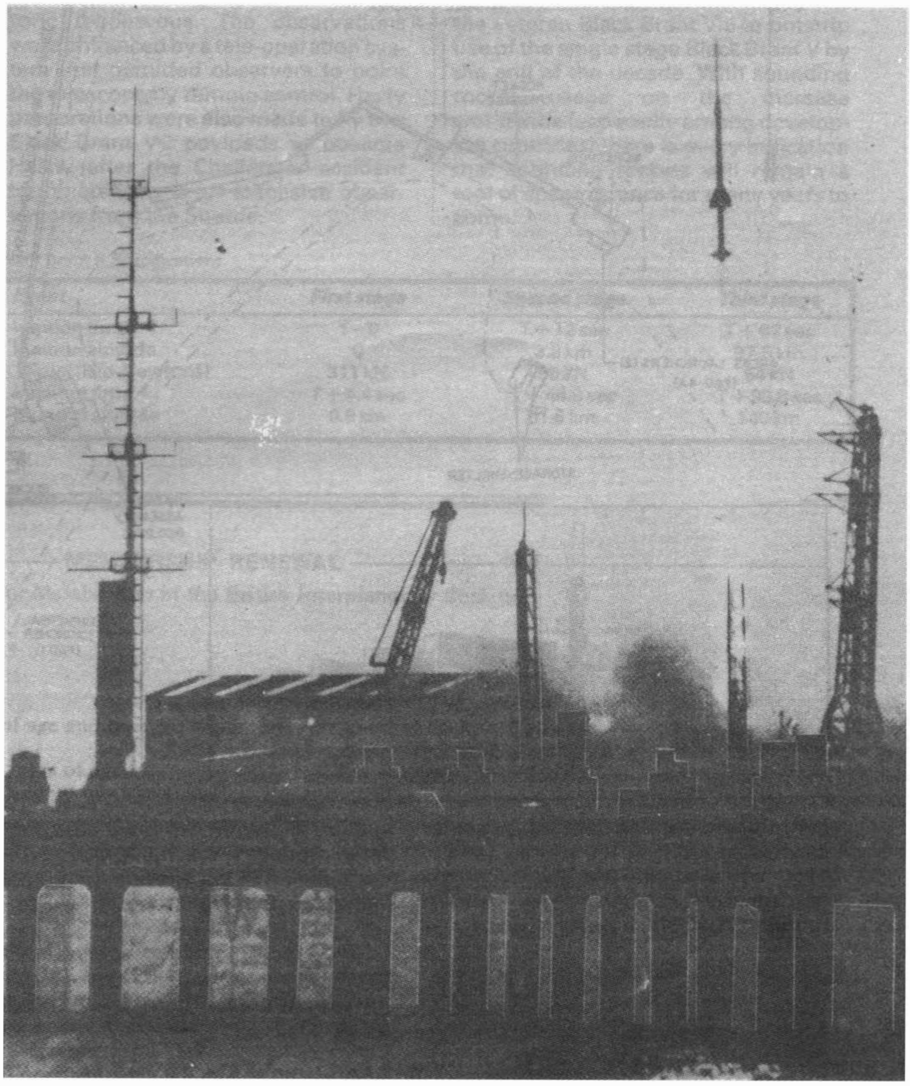
3 New York Times, 25 February, 1959, page 14, column 8
4. Watt, Erik; *May Build Rockets for Export*, Canadian Aviation, Vol 35, No 9, May 1962, page87 Alsosee *TheStoryofBristolRocketry*, Chapter 5, in *50 Years of Technology 1930-1980, Volume Two, The Second Quarter Century*
5 Sevier, H G *Canada's First Three-Stage Rocket The Bristol Aerospace Black Brant X*, Canadian Aeronautics and Space Journal, Volume 27, No.3, Third Quarter 1981, page 223

BLACK BRANT X — A Canadian Export

When the famous US Aerobee was retired in 1985 after 1C58 flights, Canadian-made Black Brants became the principal sounding rockets of the US National Aeronautics and Space Administration (NASA). The Black Brant X (and the Black Brant IX derivative) are the latest and most capable of the highly successful sounding rocket series built by Bristol Aerospace Limited in Winnipeg, Manitoba. Their continued export for use by foreign customers is here brought up-to-date by *Joel W. Powell.*

A two-stage Black Brant VIII of which more than 40 were launched from 1976 to 1981.



Black Brant IX and X

Black Brant X was born in 1979 of the need for a rocket capable of greater altitude and payload performance than the existing Black Brant VIII. NASA proposed to replace the Nike solid propellent booster with surplus Terrier motors to create the Black Brant IX, but before this vehicle could reach the launch rail an even larger rocket became necessary for a high priority project to investigate an unusual phenomenon in the magnetosphere.

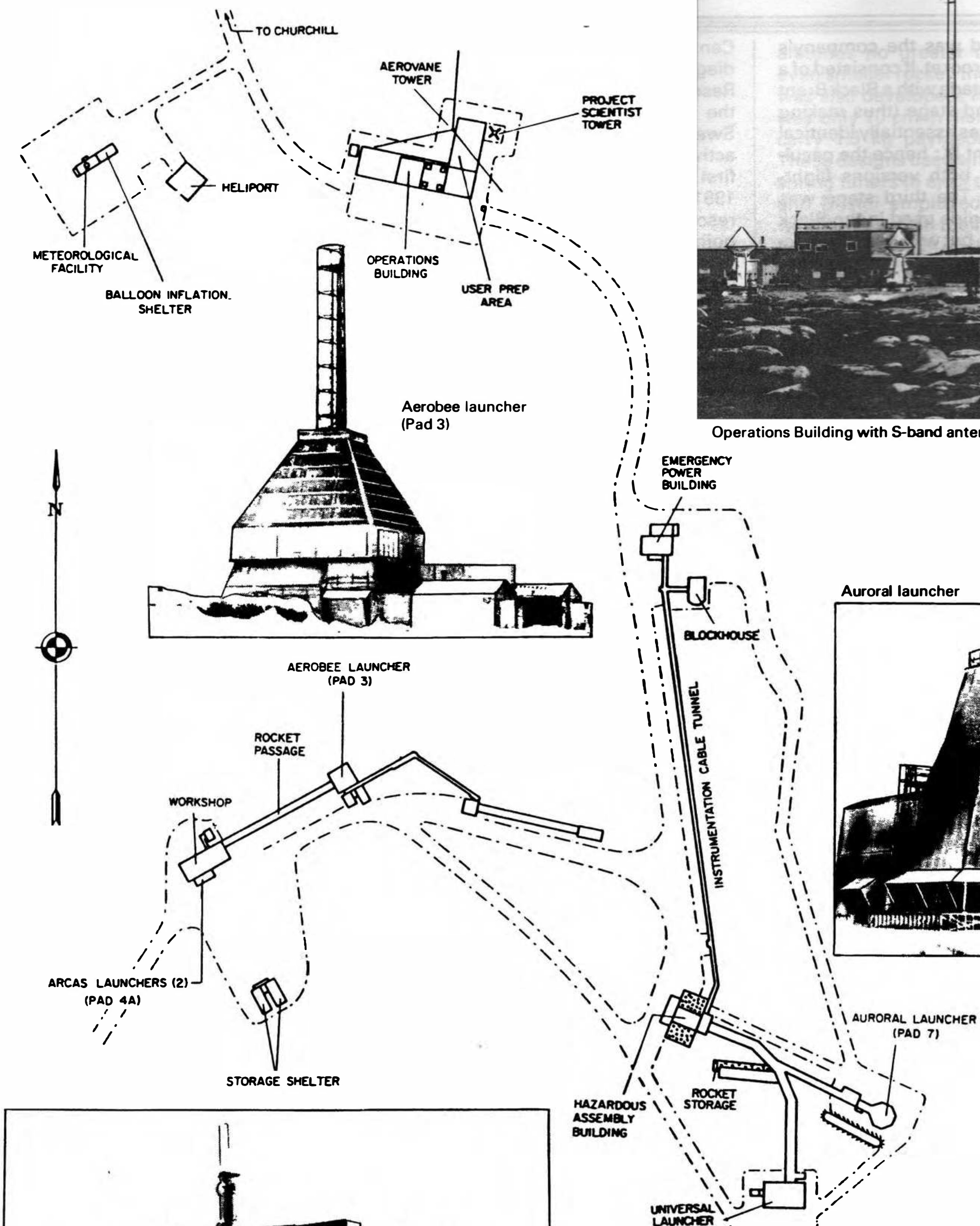
The logical solution was to provide an upper stage for the Black Brant IX, and Bristol Aerospace developed the stage as an in-house project in 1980. The resulting vehicle was designated Black Brant X and became the first three stage sounding rocket to be produced in Canada.

The new 1.6 m third stage utilised a high energy solid propellant recently developed by Bristol plus a lightweight short casing based upon the Black Brant V.

Performance and Testing

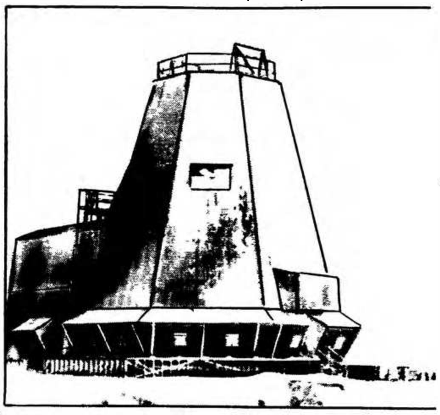
Black Brant X is 15.9 m long and 43.7

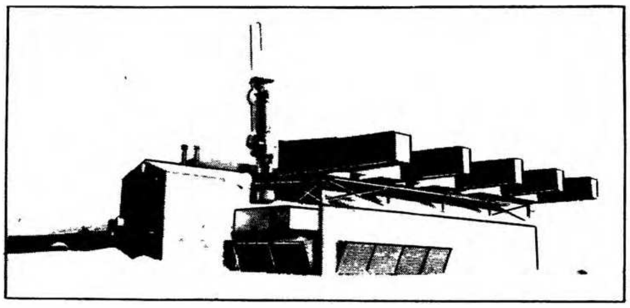
Churchill Research Range



Operations Building with S-band antenna in the foreground.

Auroral launcher (Pad 7.)





Universal launcher (Pad 1).

cm in diameter. The 2800 kg rocket is capable of lifting a 100 kg payload to 1200 km altitude. The special magnetospheric mission (see below) required that Black Brant X overfly a specific region in the magnetosphere while propelling the 105 kg payload to more than 450 km altitude for at least half of the total flight time.

Further Canadian Space projects, including communications satellites, will be presented in a subsequent issue of ***Spaceflight***

The precision guidance required for these types of missions is provided by a specially modified version of the S-19 guidance system built in Sweden for the Swedish Space Corporation by SAAB-Scania. Since its introduction in 1976 the S-19 system has been employed on Black Brant V and VIII rockets with a high degree of reliability. Payload pointing stability is maintained by a gas jet attitude control system installed on the Nihka stage (i.e. the third stage).

After four static firings of the Nihka motor, Black Brant X was first test fired on August 14, 1981 from NASA's Wallops Flight Facility in Virginia. The shot

CANADA

was an outstanding success, with the 217 kg diagnostic payload reaching an altitude of 625 km.

Black Brant IX, comprising the first two stages of the X model, was automatically qualified without the need for a separate test flight. Ironically the two stage rocket failed during its maiden launch on March 16, 1982, but has performed admirably in more than a dozen firings up to 1986.

Research Work

The first two Black Brant X's utilised for research purposes were launched from Cape Parry in Northern Canada on November 30 and December 13 1981. The rockets were the NASA contribution to Project Centaur, a joint Canadian-American investigation of the magnetospheric cusp (or cleft) phenomenon, where solar wind particles penetrate close to the Earth through a gap in the magnetic field. NASA repeated this important experiment in January 1986 with a Black Brant X fired from the Andoya rocket range in Norway.

In April 1982 NASA launched two Black Brant X's from the Poker Flat Research Range in Alaska to deploy quantities of lithium and barium vapour at high altitudes. Sunlight caused the expanding vapour clouds to glow, enabling observers to detect the presence of electric fields in space. The two rockets ascended to approximately 1500 km, the highest altitude ever attained by Canadian-built sounding rockets.

Electric fields in the magnetosphere were also the objective of a pair of Black Brant X rockets fired from Poker Flat on 30 March and 1 April 1984. Each vehicle released twin clouds of barium at altitudes of up to 950 km to locate electric fields while an aurora was in progress. Researchers believe that high altitude electric fields accelerate electrons from the solar wind into the ionosphere in a process that creates the aurora.

Two clouds of barium were dispersed from a NASA Black Brant X launched from Wallops Island on May 13 1986 (a second rocket released a quantity of strontium) to investigate a key segment of a theory of planetary formation proposed by Hannes Alfven in 1954. The experiment was intended to test predictions of plasma behaviour (the so-called critical velocity effect) during the coalescence of planets around a star as it is being formed.

Black Brant rockets were also used by NASA to obtain ultraviolet spectra and images of Comet Halley during its recent apparition. At White Sands Missile Range in New Mexico a Black Brant IX rocket was launched on 26 February 1986 with a 40 cm telescope to view the comet. After recovery the instrument was refurbished on-site and was reflown on March 13, the same day as the Giotto comet probe made its historic rendezvous. The observations were enhanced by a tele-operation system that pemitted observers to point the telescope by remote control. Hasty preparations were also made to fly two Black Brant VC payloads to observe Halley after the Challenger accident terminated plans for extensive observations from the Shuttle.

Present Status – Future Pospects

At the present time all Black Brant rockets are exported to foreign customers by the Canadian Government having cancelled all sounding rocket and balloon projects by Canada in November 1984 as a cost saving measure. The National Research Council of Canada only managed to use one Black Brant X prior to the cancellation. A similar situation developed in Britain several years ago with the Skylark rocket.

NASA and Bristol recently initiated development of the Black Brant XII, the most powerful version to date. The four stage rocket will be capable of reaching an altitude of 1600 km with an enhanced payload capacity when it enters service in 1987. The vehicle uses the top two stages of Black Brant X combined with two American-supplied solid boosters. If the need arises the first stage can be deleted to form a three stage Black Brant XI.

Demand for the Black Brants remains strong. At least 20 Black Brant X and a dozen Black Brant IX vehicles have flown to date, and Bristol expects the veteran Black Brant VIII to outstrip use of the single stage Black Brant V by the end of the decade. With sounding rocket usage on the increase worldwide (especially among developing countries) there is every indication that sounding rockets will remain a tool of space science for many years to come.

Black Brant X Specifications.

Event	First stage	Second stage	Third stage
Ignition time	T–0	T+12 sec	T+82 sec
Ignition altitude	0	3.8 km	97.5 km
Thrust (kilo-Newtons)	311 kN	89 kN	54 kN
Burnout time	T+4.4 sec	T+44.9 sec	T+99.8 sec
Burnout altitude	0.9 km	91.6 km	140 km

ACADEMY BOOK AWARD

The International Academy of Astronautics has recently awarded its prestigious Engineering Sciences Book Award to two BIS Fellows, Dr. David J. Shapland, Head of the Promotion and Astronaut Office of ESA in Paris and Dr. Michael J. Rycroft, Head of the Atmospheric Sciences Division of the British Antarctic Survey, based in Cambridge.

The award is for their book 'Spacelab: Research in Earth Orbit' published by Cambridge University Press (£12.95). With the aid of unique colour photographs the book covers the full technical development of Europe's first manned laboratory in space and documents a broad spectrum of scientific experiments ranging from astronomy to zoology.

BIS OFFICERS FOR 1987

At its meeting in November, the BIS Council re-elected Mr. C.R. Turner as President for a third one-year term. Dr. L.R. Shepherd and Mr. G.W. Childs were both re-elected Vice-President for a further year.

Following the recent elections to Council (reported in the December issue of ***Spaceflight***) the membership of the BIS Council for 1987 is as follows:

President: C.R. Turner

Vice-President: G.W. Childs, Dr. L.R. Shepherd

R.A. Buckland, Dr. J.K. Davies, M.R. Fry, Prof. G.V. Groves, C.R. Hume, A.T. Lawton, Prof. I.E. Smith, G.V.E. Thompson, G.M. Webb

SOCIETY MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

28 January 1987, 7-9 p.m. **Film Show**

THE BORDERS OF SPACE (Part 1)

Two film shows will highlight important stages in the development of manned space exploration.

The programme will include the following:

(a) The Legacy of Gemini.
(b) Apollo 15: To the Mountains of the Moon.
(c) Four Rooms, Earth View (Skylab).
(d) STS-2: Post-Flight Press Conference.
(e) STS-5: Post-Flight Press Conference.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

25 February 1987, 7-9 p.m. **Film Show**

THE BORDERS OF SPACE (Part 2)

The second of two film shows continues the survey of important manned space missions.

The programme will include the following:

(a) The Four Days of Gemini 4.
(b) The Mission of Apollo-Soyuz 15.
(c) STS-6 Post-Flight Press Conference.
(d) STS-9: Post-Flight Press Conference.
(e) The Space Station.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

11 March 1987, 7-9 p.m. **Lecture**

WHEN IS SPACE NEWS?

by F. Miles

Once, in the days of Apollo, there was tremendous television and press interest in space. Now it seems to take something like the Challenger disaster to arouse media interest. What *are* the constraints on reporting space news? How *do* editors decide what is worth reporting? Frank Miles has been handling space stories on ITN since the 1960 — and might have some answers.

29 April 1987 **Symposium**

FUTURE SPACEPLANES

A follow-up to the successful Hotol Symposium in November 1986. 'Future Spaceplanes' will be held at Millbank Tower, London SW1. Registration 9am, first lecture 9.30am. Programme to be announced shortly. Registration forms available from The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

6 May 1987, 7-9 p.m. **Lecture**

REVIEW OF THE SOVIET SPACE PROGRAMME

by P.S. Clark

For more than a decade, in terms of launch rates, the Soviet Union has dominated space activity. Many aspects of its space programme are shrouded in secrecy but a careful study of public information allows insights to be obtained into Soviet space programmes. Phillip Clark has been analysing the Soviet Programme for nearly two decades, and will present a review intended for the non-specialist of recent development and the future direction of the programme.

6 June 1987 **Symposium**

SOVIET ASTRONAUTICS

Further details to be announced.

LIBRARY

The Society Library will be open to members from 5.30 p.m. to 7 p.m. on the following dates:

28 January 1987
25 February 1987
11 March 1987

TRANSFER TO FELLOW

Under the Society's new Constitution and revised Bye-Laws, many Corporate Members (i.e. members whose date of election is earlier than 31 December 1985) now become eligible for transfer to Fellow. On Payment of their renewal subscription for 1987, Corporate Members will automatically be considered for transfer to Fellow and notified in due course. No individual application is required as the subscription rates for the two grades are now the same (£28.00, US$42.00)

Any Non-Corporate Member may apply at any time for transfer to Fellow on the basis of contributed work. Details are available on request.

Fellows are entitled to use the designation F.B.I.S.

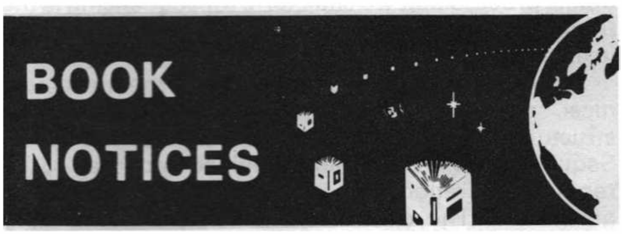
* * *

Any member who renews for 1987 by payment of the rate applicable to Non-Corporate Membership (£22.00, US$33.00) will be automatically transferred to that grade.

QUICKER OVERSEAS DELIVERY

Arrangements have now been made for overseas readers to receive their copies of ***Spaceflight*** much more quickly. With effect from this issue, ***Spaceflight*** will be sent by accelerated surface mail. The new service is being made available at no extra charge.

If all goes well, some readers, especially those at more distant addresses, may receive this issue ahead of that for December. Should this occur, please understand that the December number is following via the normal surface route.



Exploring the Night Sky with Binoculars

Patrick Moore, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1986. 203pp. £11.95.

Some people invest in a telescope to explore the night sky but, for others, stargazing through binoculars can be just as rewarding and can just as easily lead to the wish for a deeper knowledge of the universe around us.

The author uses this work to reach such people, beginning with an explanation of the rudiments of astronomy and the selection of binoculars, before discussing the array of superb astronomical objects which it can show.

Every object mentioned in the book has been examined by the author personally, using several pairs of binoculars for test purposes. He charts the night sky, season by season, and follows this with detailed descriptions, with maps of all the constellations, adding further comments on the use of binoculars for observing the Moon and planets.

Space Commerce

N. Goldman. Ballinger Publishing Company, Cambridge, Massachusets. 1985. 176pp. $25.

Sub-titled 'Free Enterprise on the High Frontier', this timely analysis of space commerce provides a fascinating glimpse of the next horizon of human economy and society.

Drawing on economics, law and political science the author presents a model for space commerce, covering space transportation, communications, satellites, remote sensing satellites and space manufacturing.

The nine chapters lay out the origin and structure of space commerce globally, the space programmes and policies of spacefaring powers and some critical issues for decision-makers in government and private enterprise as we operate in a new realm of advanced technology competition.

Of Stars and Men

Zdenek Kopal, Adam Hilger, Techno House, Redcliffe Way, Bristol BS1 6NX. 1986, 486pp, £29.50.

The 20th century has been a remarkable epoch in the affairs of men, a factor no less true in astronomy which now emerges as the oldest yet the most modern of the sciences.

At the beginning of this century most sky watchers were measuring positions and predicting celestial motions: nowadays, their modern counterparts call upon all the resources of modern technology to probe the nature and evolution of what has become a bewildering range of celestial objects.

The author remembers well the more leisurely days when scholars commanded such respect that astronomical congresses were visited by Heads of State. Yet, within his own life, Kopal has played an important role in the scientific preparations for a manned lunar landing.

This is an excellent book and everyone interested in background developments in astronomy will enjoy reading it.

Guide To The Stars

L. Peltier, Cambridge University Press, 32 E. 57 St., New York, NY 10022. 1986, pp.185, $11.95.

This is a book for the beginner written by an amateur astronomer of many years' standing who was not only active in the area of home-built telescopes but discovered 12 comets and four novae in the process.

His latest book is aimed at making the night sky intelligible to the casual observer – with the aid of many maps, much background information and advice on keeping a record of stellar observations which the keen amateur can complete for himself.

However, the book is not restricted solely to the stars. Additional notes are provided on observing the Sun and Moon, the planets, comets and meteors.

Photoquiz

Answer. **The coastline is that of the eastern Mediterranean. The large 'lake' is the Dead Sea, above which is the Gulf of Akaba.**

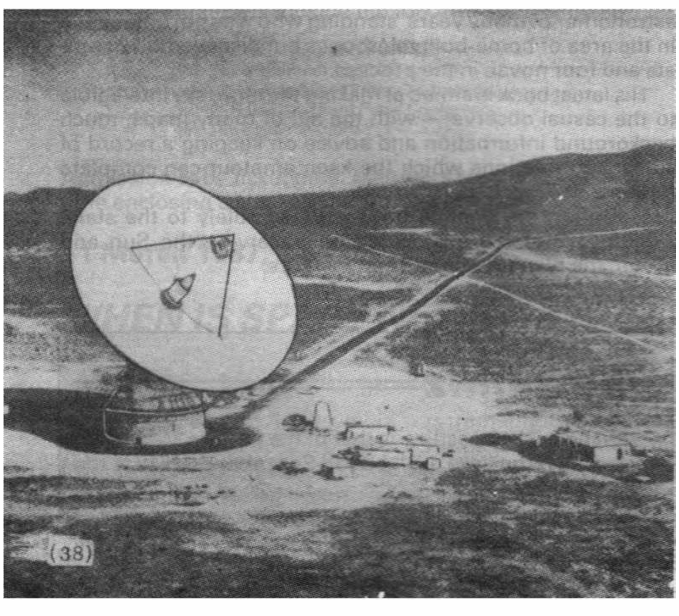
How to Feed a Spacecraft

Spacecraft are voracious creatures. They live upon a diet of bits sent from Earth and arranged into patterns that fill the on-board computers with instructiions on how to carry out day-to-day operations. Technically, the process that starts with the opeartional desires of scientists and engineers and ends with the transmission of a set of commands for use by the spacecraft's computer is called the "uplink". The transmission of data from the spacecraft and the subsequent reception, distribution, and analysis is called the "downlink". From two thirds to three quarters of a project's effort during operations centres upon the uplink, and some features of its structure will be examined.

The task of producing a "load" for the on-board computers further fits the feeding metaphor because the bits are not continually sent to the spacecraft but, rather, are periodically uplinked as "meals". These meals serve to nourish the spacecraft from time spans of 12 hours to six months, depending upon the type of spacecraft and the phase of its mission.

Not all of the instructions for the spacecraft are sent as part of a load. From time-to-time, supplementary "real-time commands" are transmitted by the flight team (yes, spacecraft snack between meals). The real-time commands can serve a number of purposes: modify spacecraft behaviour to adapt to a changed environment since the ongoing load was built (often new knowledge, such as improved navigation data, by the flight team); correct errors discovered in the ongoing load; supply commands for which there was no room left in the original load; start or stop a critical branch of the load that needs the insight of last-minute judgment; or just say "hello". The last item is not as social as it sounds. Spacecraft often carry a command-loss timer so that if they receive no commands from Earth within a specified period of time, they take an autonomous set of actions based upon the assumption that their receiver has failed and the link to Earth has been severed (see the June 1986 edition of this column for the Voyager "backup mission load").

View of the dish antenna of the US Deep Space Network in the high desert area near Goldstone, California.



In order to emphasize the distinction between real-time commands and the sequence of commands contained in a load, the latter is often called a "sequence load" or just a "sequence". To complete the lexicon, the practice of producing sequences is called "sequencing", and it is to this fundamental part of the uplink process that we shall turn, for sequencing is the thread of activity upon which the flight team orients itself during operations.

As with most human activities, even the most technical, sequencing has a readily understandable overall structure, before a welter of details is encountered. Sequencing, like Gaul, can be divided into three parts: request generation, request integration, and sequence generation. The conclusion of this process is then accomplished by transmitting the sequence (load) to the spacecraft.

Request generation begins with a sequence request, which is, as the term implies, a petition by a spacecraft user to include a certain activity in the sequence that is being designed. For example, the representative of the imaging team might request that the spacecraft's camera be pointed at a designated star and a series of images taken, each with a specified filter and exposure time. A member of the spacecraft team might request that the antenna pattern of the spacecraft's high-gain antenna be calibrated, to optimise the gain of the communication link with Earth. A request from the navigation team might be to perform a trajectory-correction manoeuvre.

A significant fraction of these requests will come as no surprise, since mission planners will have previously polled project elements to establish the major requests that will probably populate each phase of the mission. This planning is necessary in order to give forethought to meeting all project objectives and to avoid the unpleasant surprise of having too many sequence requests pile up at once. For periods of high science activity, such as planetary encounters, science planners will have generated in advance of the actual sequence design a detailed plan of activity. Also, scientists and engineers usually know throughout the mission the location of major calibration activities for instruments and engineering subsystems. The strategy for trajectory correction manoeuvres is normally worked out well in advance, yielding the temporal placement of the manoeuvres prior to the design of the sequences in which they will be placed.

The sum of all requests for a given sequence will frequently exceed the resources available to implement

The Voyager 2 Spacecraft depicted by artist *Julian Baum* during its close encounter with Neptune's moon Triton which will occur in August 1989. © *Julian Baum*

it. The size of the on-board computer is one limitation; the number of hours required by the flight team to build the proposed sequence is another. A third limitation is the antenna coverage that will be available from the Deep Space Network; sequences, of course, generate data that must be downlinked. The project may deny a request on the grounds that it uses too much of a critical consumable or represents an unacceptable risk to the spacecraft or mission.

In a series of meetings, the requests will be subjected to prioritisation, reduction in scope, or deletion. Finally, a set of requests emerges which, it is believed, can be fashioned into a sequence that meets project needs: request generation is complete.

The second phase of sequencing is request integration . The sequence requests are arranged into a time order that optimally matches spacecraft and ground capabilities. The integration phase requires the most creativity from sequence designers because a large number of factors influence the placement of activities. For example, except during critical mission phases, engineering teams are fully staffed only during normal working hours, so that sequenced activities which need special monitoring by the flight team should not be placed at night, or on weekends, or on holidays, if possible. In order to avoid switching instruments on and off (cycling can affect lifetime of the instrument), two instrument-usage requests should be placed in close proximity, if possible, and many other rules of good sequencing are similary invoked in this design phase.

Another series of meetings is held from which the approved integrated timeline for the sequence emerges. This timeline is usually displayed in graphical form and represents a plan for the sequence. See the following piece, "Automated Sequencing", for the assist that artificial intelligence techniques may soon be giving human sequencers in the development of such timelines.

The third phase, sequence generation, could in principle be done by a computer programmer sitting down and writing code for the spacecraft's computer. However, this labour-intensive activity would take longer than the time that is available during a mission and would result in too many errors being introduced into the sequence. Instead, the required programming is done by a set of ground-based computer progarams: the JPL Mission Sequence Software (MSS). One staple of the MSS is a program called SEQGEN (sequence generator) which conducts part of the programming task and checks numerous constraints that each sequence must satisfy, e.g., do not point the camera too close to the Sun while imaging.

A second aid to sequence generation arose from the realisation that certain activities, such as trajectory correction manoeuvres, are repeated time and again throughout a mission. These activities are captured in skeleton form by pieces of software known as "blocks" or "components." For a specific application, the parameters for the case at hand are inserted into the block, and the MSS expands the block automatically into the full set of commands for the sequence. Since blocks and components are tested thoroughly before use, this method adds both efficiency and reliability to sequencing. Project Galileo has over 100 sequence components available for use.

The output of the sequencing process is a "ground command file" which is sent to the appropriate Deep Space Station, at Goldstone (California), Canberra (Australia), or Madrid (Spain), and uplinked to the spacecraft. Voyager sequence loads usually take somewhat over an hour to transmit to the spacecraft and may be sent more than once to insure reception.

Although sequencing is a highly structured activity and usually proceeds according to plan, it can become one of the most dramatic parts of a mission. As Voyager 2 sped towards its meeting with Uranus on January 24, 1986, sequencers raced against time to encode the latest navigational data into a revised sequence. Ground computers hummed and accuracy checks were made of their outputs. Finally just a few hours before the crucial portion of the sequence was to be executed on board the spacecraft, the critical updates were received from Earth. The corrections to camera pointing and other key parameters yielded a near-perfect encounter.

Automated Sequencing

Will there come a day when a human on Earth can speak to a computer, and a spacecraft, millions of kilometres away, will respond? That day is still quite distant, but it has been brought closer by recent advances in spacecraft sequencing.

Spacecraft sequencing, described above as the generation of on-board computer programs to direct the day-to-day activities of a spacecraft, is currently facilitated by an extensive set of ground-based computer programs. Now, new sequencing methods involving expert systems and artificial intelligence are being introduced at JPL to supplement classical techniques, i.e., "symbolic processing" is being employed. Specifically, that part of sequencing which involves the construction of a "timeline" (a graphical display of planned spacecraft events and associated ground events) is being increasingly automated by use of symbolic processing techniques; symbolic processing thrives upon knowledge bases, constraints, and rules of inference, while classical programming is more numerically oriented and exhibits only relatively simple and rigid decision making.

Last October 30 a demonstration was given at JPL of the ability of symbolic-processing software to produce a graphical timeline from science and engineering desires typed into the computer in English. The demonstration of concepts was founded upon a simulated week in the mission of the proposed Comet Rendezvous Asteroid Flyby (CRAF) spacecraft. The purpose of the demonstration was to display the capabilities of this prototype software, which has been developed by the Laboratory's Sequence Automation Research Group, in order to solicit comments and suggestions from potential users at JPL.

The software consists of two principal parts:

(1) A program which translates the English-language text of sequence requests, typed into the machine, into a data base, and

(2) A program which, using symbolic-processing techniques, derives a time-ordered sequence of spacecraft activities that carries out the original requests. The activities are displayed graphically in the form of a timeline for ease of comprehension.

The translator, called a "parser" – according to the

dictionary a sentence is "parsed" by resolving it into its component parts and describing them grammatically – was developed by Dr. Boris Katz of MIT; Katz is a research scientist in MIT's Artificial Intelligence Laboratory.

In addition to its parsing capability *per se,* the parser contains an inference engine, i.e., it can perform simple deductions. The practical importance of the inference capability is that the human can test the data base constructed by the parser to insure that it has correctly represented the English text. The test consists of simple questions posed to the machine. For example, if the parser has been fed the sentence "Load the imaging table into the spacecraft's memory," the question, "Is the imaging table in the spacecraft's memory?" would be answered "yes". As elementary as this result is – the program has pursued the logical implication of the verb "load" – it is a good indicator that the parser translated and stored the material which it was given.

An important application of the parser, outside of the scope of the CRAF demo, is as an aid to date-base construction. Most projects have large quantities of information which they wish to capture and retain in a centralised location. This information can be of a numerical nature or, more commonly, it may be statements of project rules and requirements. The parser represents one way to assemble this store of data and, with the above-mentioned interrogation feature, the data base is rendered more useful. The larger the project the more difficult informatiion storage and retrieval becomes, so that Space Station would be a strong candidate for utilization of this technique.

The third application of the parser, in addition to interrogation and data basing, is the one that is relevant to the CRAF demo: interface with other systems. Here, the other system is the symbolic processing program PLAN-IT, built by the Sequence Automation Research Group. In the past, PLAN-IT has been used for a variety of scheduling and planning problems related to Space Station and to Deep Space Network antennae. The PLAN-IT program and the parser program are written in the language LISP, which is the most widely used language in the field of artificial intelligence. The CRAF demo represents the first application of PLAN-IT to the problems of planetary missions. The planetary capability will be institutionalised at JPL by incorporating the software into the Laboratory's Space Flight Operations center, now under construction (see the October 1985 *JBIS* for a discussion of this facility).

The primary function of PLAN-IT is to arrange the requested spacecraft activities relative to one another such that no conflicts over resources occur. For example, one must avoid using too many instruments at an instant of time such that electrical power from the spacecraft is oversubscribed or more data is generated than the spacecraft's data system can handle.

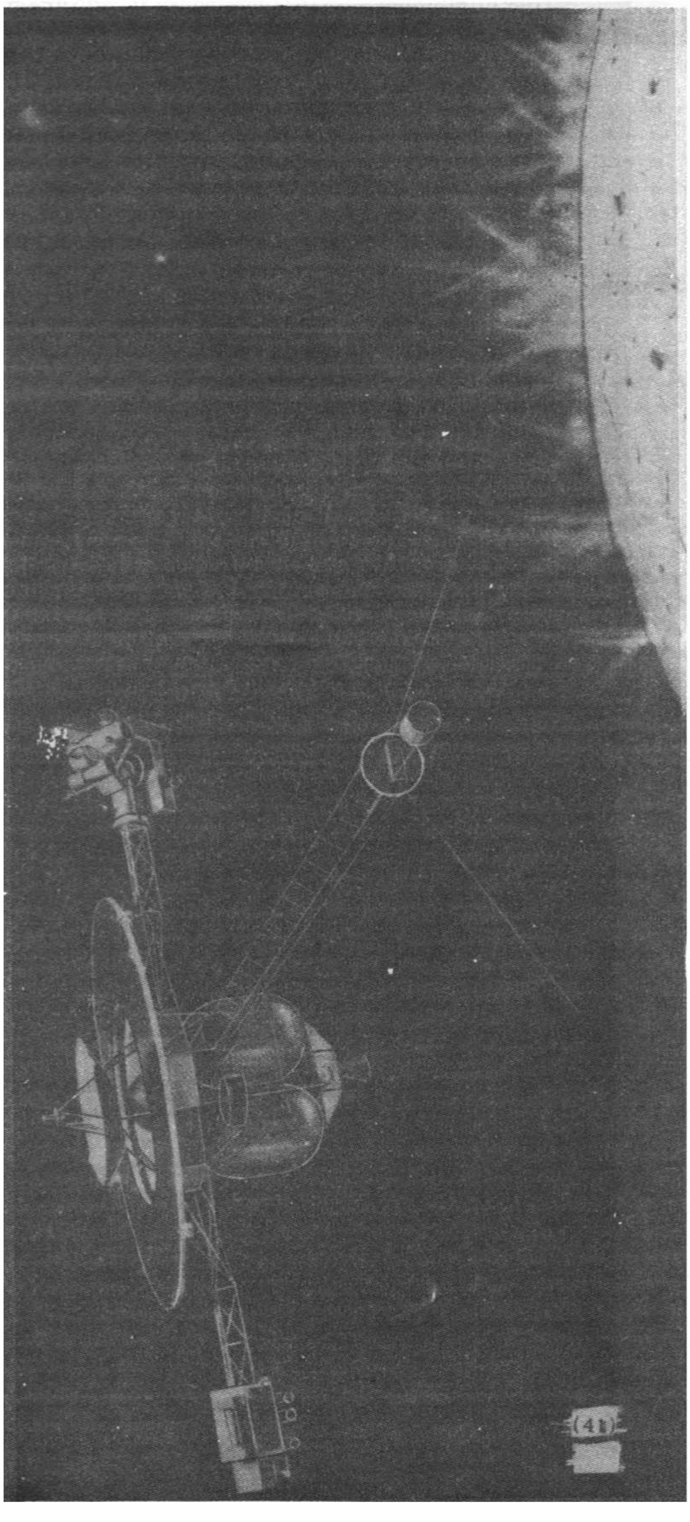
The strategies by which PLAN-IT copes with conflict resolution are of two basic types and are selectable by the user. The first type is the set of global strategies, i.e., the machine attacks the whole scheduling problem and attempts to produce a timeline of events that is free from conflict. The user chooses the strategy which seems most appropriate at any stage in the development of the timeline. The second type of strategy is local. At any stage, the current conflicts are displayed on a television monitor screen and the user can specifically identify portions of the developing timeline that are particular trouble spots and, by selecting the appropriate local strategy to deal with that trouble spot, give, in effect, advice to the computer.

The interplay between human and computer is extensive in the current system. In time, the automatic features of the system will probablly increase at the expense of human participation. But, unlike chess-playing programs, it is not a goal to eliminate human participation; the goal is to produce good timelines in the most cost-effective manner.

So, the day that sequencing is totally automatic is probably a long way off. Nevertheless, it is at least intriguing to imagine walking up to a computer, saying "I want to go to Mars," and having mission and spacecraft designs pop out!

Future editions of this column will explore other artifical-intelligence activities at the Laboratory.

Artist's representation of the Comet Rendezvous Asteroid Flyby (CRAF) spacecraft.



Space at JPL

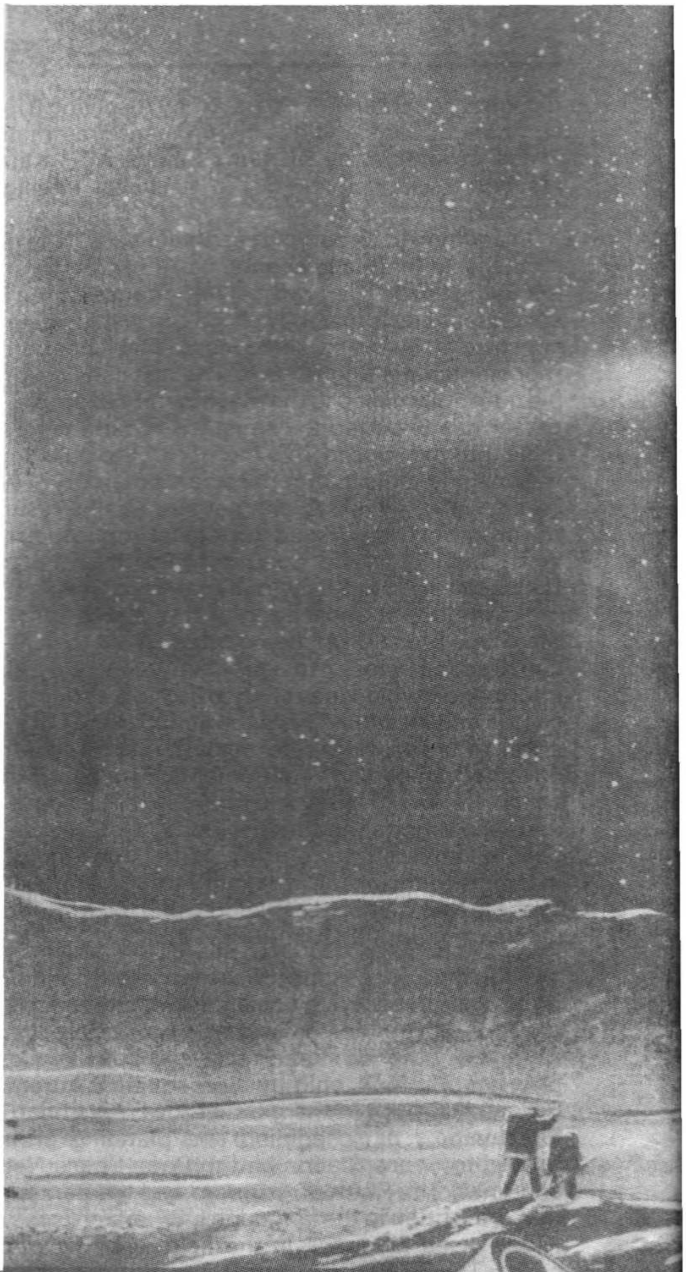
Towards the Stars

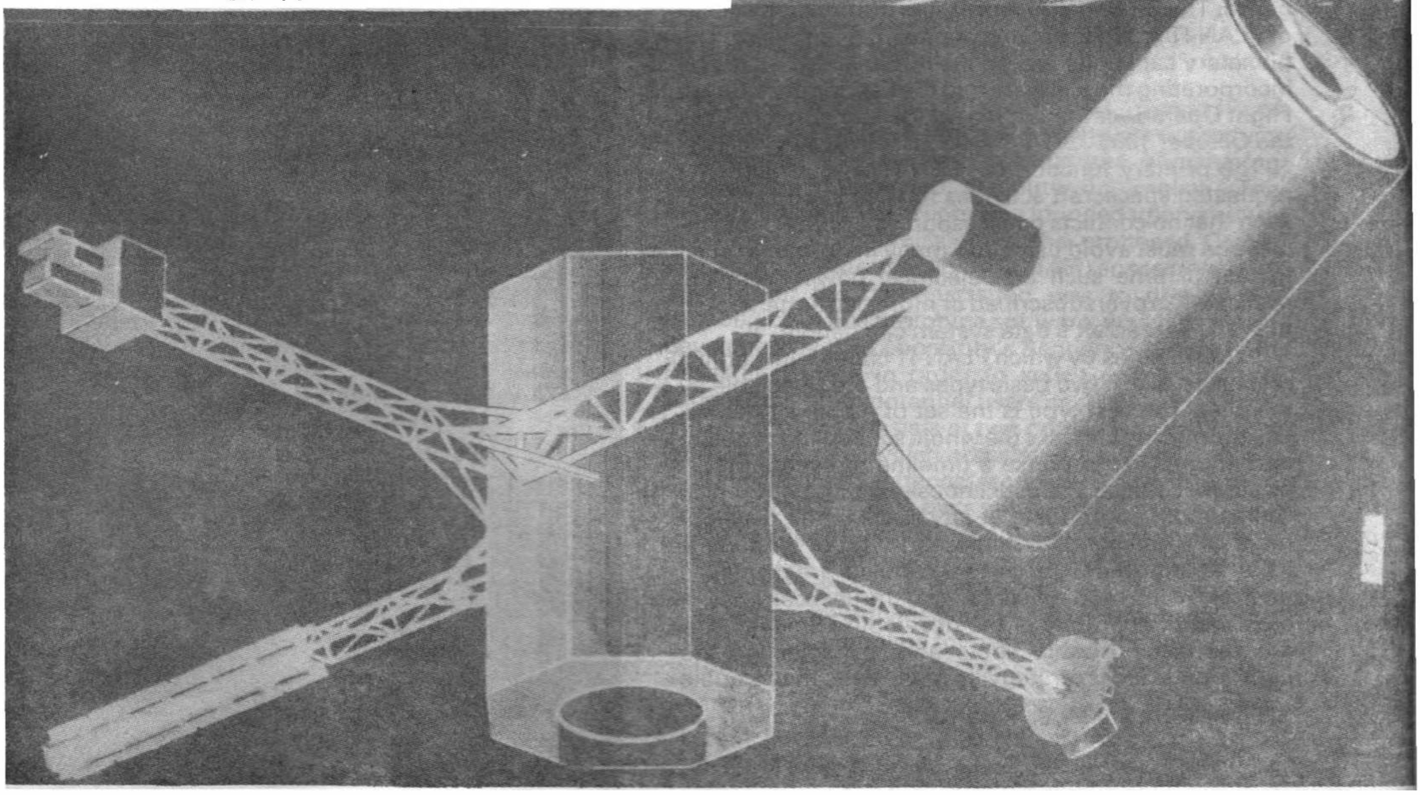
The case for interstellar flight has been made with vigour through the pioneering work of Dr. Robert Forward, through the Society's Daedalus project, and in the pages of the *JBIS* "Interstellar Studies" issues. And with Voyager 2 rushing toward an August 1989 encounter with Neptune, the Solar System should soon be spanned, if only lightly explored. But what of the region between the planets and the stars – what plans exist for missions to this domain? It seems natural to probe cis-stellar space before making the long trek to the stars.

Perhaps the first serious investigation of this problem was conducted at JPL by Dr. Leonard Jaffe and collaborators in the late 1970s (see *JBIS*, Vol 33, pp 3-26). This Interstellar Precursor Mission (IPM) presented a plan to send a spacecraft into the region of 400 to 1000 A.U. from the Sun. An astronomical unit (A.U.) is the distance from Sun to Earth, approximately 150 million kilometres. To obtain a feel for the scale of this endeavour, note that Neptune is approximately 30 A.U. from the Sun, while Proxima Centauri, the nearest star, is over 270,000 A.U. from the Sun. Thus, the mission would not have come close to being interstellar, but it would have extended a significant distance beyond planetary space.

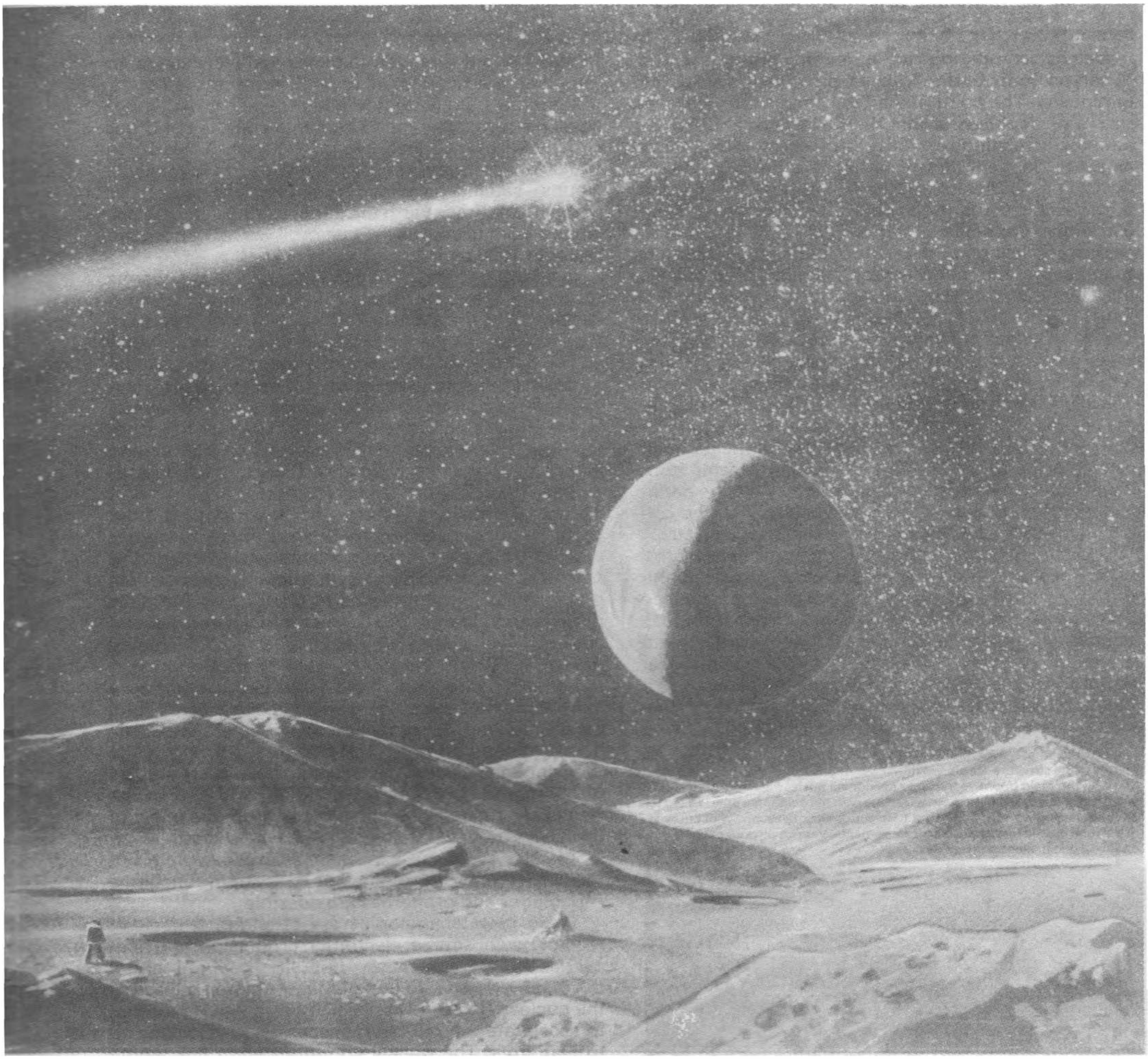
The objectives of IPM, planned to last from 20 to 50 years, were both scientific and engineering, with the latter pointed towards addressing some of the technological problems associated with interstellar flight. The primary scientific objectives included studies of the interstellar medium and cosmis-ray particles and the determination of stellar distances by parallactic measurements.

Parallactic measurements are based upon the astronomical fact that the nearer stars are seen to shift their positions against the background of distant stars as the Earth moves around the Sun during the year.





The TAU spacecraft is shown after it has been separated from the propulsion unit. The 1.5m astrometric telescope, contained in the cylindrical tube, is used for parallactic measurements. The 1.0m telescope for communications with Earth is contained in the octagonal tube. Physics experiments and RTGs (for electrical power) are placed on the other booms. NASA/JPL



Future visitors to the planet Pluto watch as an interstellar probe leaves the Solar System on a journey to the stars © R. Miller, Bantam Books.

The "parallax" of a star is defined to be the maximum apparent angular displacement it undergoes, measured in seconds of arc, as the Earth moves through one quarter of its orbit. Then by simple trigonometry the actual distance to the star is calculated to be 1/p parsecs, where p is the parallax in arc seconds. The parsec, an astronomical unit of distance defined by this relation, is equal to approximately 3.26 light years.

The first stellar parallax was measured in 1838 by F. W. Bessel for the star 61 Cygni and found to be 0.294 arc seconds (3.4 parsecs). Until that time, the lack of detectable stellar parallaxes was counted as a mark against the Copernican heliocentric theory, and, in fact, the great seventeenth-century Danish astronomer Tycho Brahe rejected the Copernican theory on these grounds; his astronometric methods, the best of the day, were only good to an accuracy of about 60 arc seconds.

The IPM study was an interesting start, but it left many questions unanswered. A new study has been undertaken at JPL: the Thousand Astronomical Unit (TAU) mission. It brings new ideas and technological advances to the plans for penetrating cis-stellar space.

If TAU were to become a funded project, a launch in about 2005 is envisaged with a mission duration of 50 years and, as the name implies, a penetration of cis-stellar space to a distance if 1000 A.U.

Study scientists Marjorie Meinel and Dr. Aden Meinel are leading the scientific definition of the TAU mission. Five principal areas of investigation are being examined: (1) stellar parallaxes, (2) the heliopause, (3) the interstellar medium, (4) galactic science/astrophysics, and (5) solar-system science.

The first rung of the cosmic distance scale is provided by parallactic measurements for nearby stars. To measure the distance of objects beyond the range of this method, the period-luminosity relations of Cepheid variables can sometimes be utilised. It turns out that the absolute brightness (luminosity) of one of these variable stars is closely related to the period of its variation. The latter quantity can easily be timed by astronomers and then, using the relation between period and luminosity, its luminosity can be calculated. A second calculation yields the Cepheid's dis-

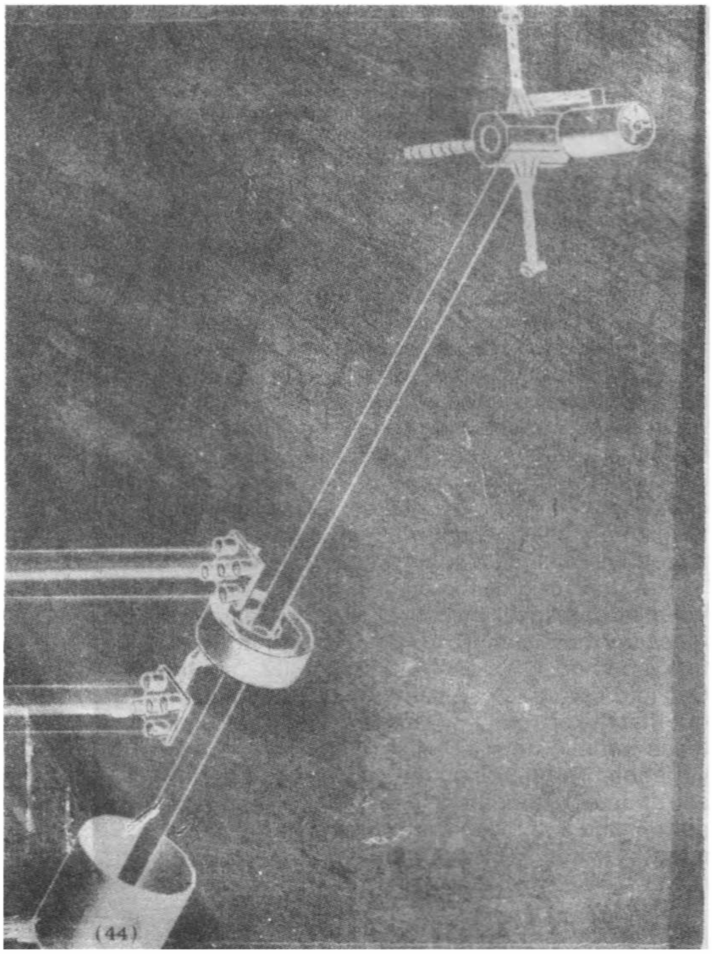
tance by comparing its apparent brightness, as observed from Earth, with its previously calculated luminosity. The point of the TAU parallactic measurements of Cepheids is that their all-important period-luminosity relations can be more accurately calibrated as more Cepheid distances become directly known. According to Assistant Study Scientist Dr. Bonnie Buratti, TAU could measure the distances of at least 600 known Cepheids.

One application of the period-luminosity relation is to measure the periods of Cepheids in a galaxy, thereby allowing the calculation of that galaxy's distance.

A second astrophysical method of measuring distance is based upon relations between colour and luminosity in various classes of stars (as shown in the so-called Hertzsprung-Russell (HR) diagram). By measuring the colour and using the HR diagram to infer luminosity one can, as with the Cepheids, then calculate the approximate distance to the star from observation of its apparent brightness. With the parallactic determination of distances using TAU, the colour-luminosity relation can be defined more exactly.

Both the Cepheid and the HR methods are, in turn, used to calibrate the redshift technique of calculating the distances of very distant objects. One consequence of the expanding universe is that the light from sources outside our galaxy is doppler shifted toward the red end of the spectrum. Using the distance-redshift relation (Hubble's law), one can estimate the distance of a galaxy after measuring its redshift. Comparing this distance, for nearer galaxies, with that obtained by using Cepheid or HR methods for those galaxies yields an improved precision for all redshift measurements.

In this conceptual design for the TAU spacecraft, the 10 ion engines near the middle of the structure are shown thrusting. At one end of the spacecraft, coaxial with the main boom, is the large cylindrical nuclear reactor. At the other end are two telescopes; the 1.0m telescope with the octagonal tube is used for communication with Earth, and the 1.5m astrometric telescope with the cylindrical tube is used for parallactic measurements. Various physics experiments are hung on smaller booms at this end *NASA/JPL*



With the 1.5m astrometric telescope on TAU, long-baseline parallactic measurements could extend our knowledge of accurately known stellar distances out to 500,000 parsecs, which would include the Magellanic clouds – satellite galaxies of our Milky Way galaxy. For comparison, from Earth the limit is about 120 parsecs, while a 1.5m telescope in Earth orbit would be effective to about 1000 parsecs.

In addition to improving the accuracy of the cosmic distance scale, TAU parallactic results would sharpen the model of the structure of our galaxy by determining the location of many of the stars which comprise it.

The heliopause, the second area of TAU investigations, is the region where the influence of the solar wind yields to interstellar dynamics. It may be somewhere between 50 and 100 A.U., or even further, from the Sun. TAU could measure the dust distribution across the transition zone and characterise the fields and particles environment of this region

The interstellar medium has been studied from Earth by remote sensing methods, but *in situ* studies with TAU would provide an unparalleled chance to gain insight into this pervasive structure; composition, magnetic field strength, plasma waves, and energetic particle populations could all be characterised. Several astrophysical studies are being considered, including gravitation-wave detection, local galactic gravitational-field structure, and low-frequency radio astronomy (not possible inside the heliosphere). And, of course, the astrophysical benefits of parallactic measurements augment this category.

Among the solar-system scientific goals are studies of the dust distribution (by imaging) and determination of the total solar-system mass (from the effect of that mass upon the trajectory of the spacecraft).

The design of the spacecraft is still evolving, but some preliminary estimates of subsystem functional capabilities and properties are possible.

Three new technologies are required: a nuclear-reactor power source, electric ion propulsion, and optical laser communication, but all three are under development. The first two items would be utilised in the nuclear electric propulsion system that is required to accelerate the 24,000 kg spacecraft to velocities up to 100 km/s. The optical communication link would allow data rates up to 20 kilobits per second at 1000 A.U. – approximately the maximum achieved by Voyager 2 at Uranus, at a range of 20 A.U., using radio communication (at X-band). The "antenna" for TAU would be a one metre optical telescope, distinct from that used for scientific observations.

The payload of the spacecraft is estimated to be about 3000 kg, with 21,000 kg allocated to propulsion, including a 4000 kg reactor. The spacecraft itself would be separated from the propulsion unit after termination of thrusting (10 years) and would slowiy rotate about the axis of the optical-communications telescope. This rotation sets the limit of the maximum exposure time and, hence, the faintest star that can be seen: about 23rd magnitude.

The ion engines, thrusting perpendicular to the long axis of the 40m vehicle, would send TAU out of the solar system in the plane of the ecliptic and toward the apex of the solar motion, i.e., where the heliopause would be closest to the Sun.

It is refreshing to see a mission on the drawing board that could extend our explorations to some of the ranges that match our imaginations.

FEBRUARY 1987 $3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

* * *

Spaceflight is distributed in the UK through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone 0344-884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, (No. 402498). Registered office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

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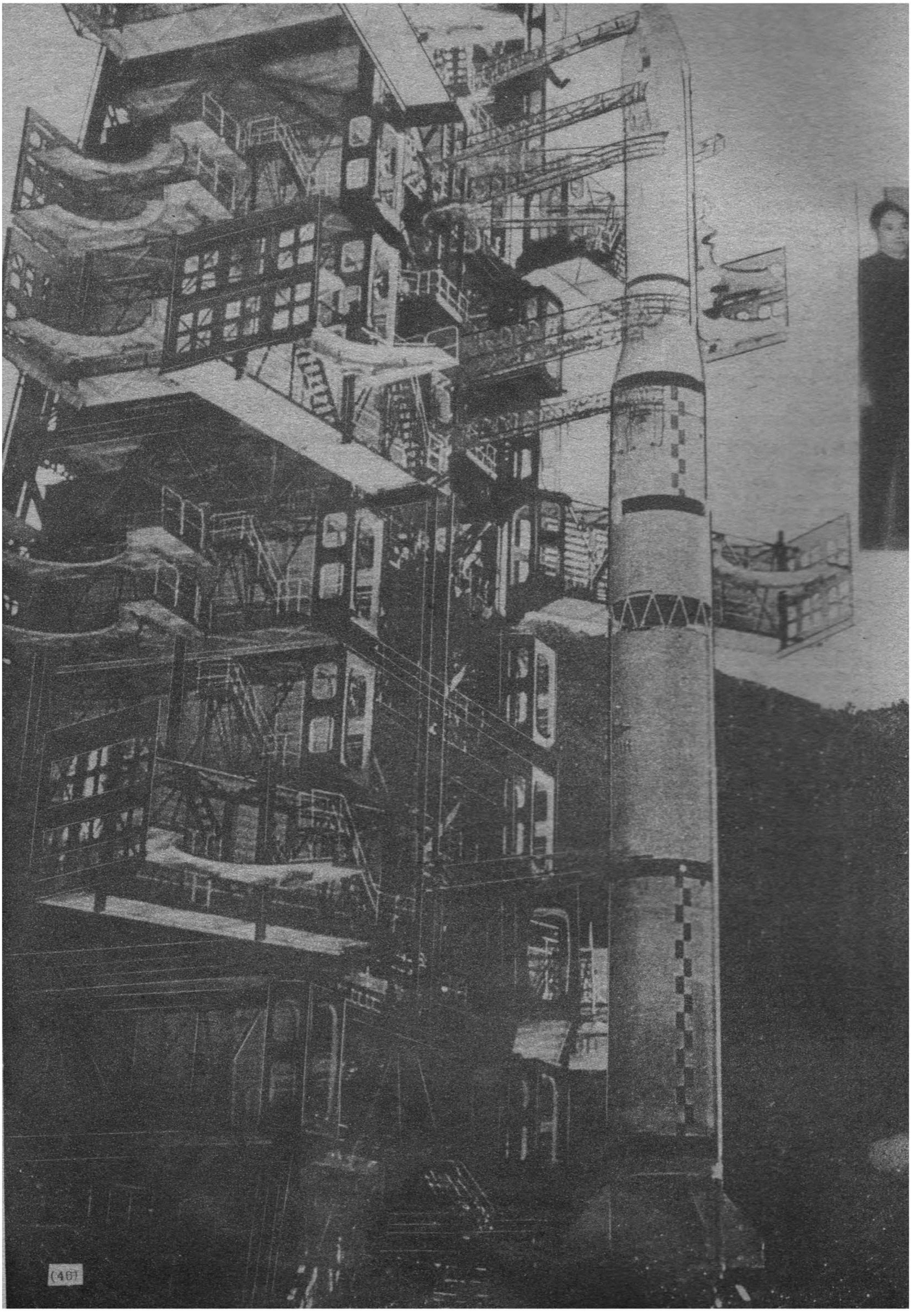
ISSN 0038-6340

Vol. 29 No. 2 **February 1987**

В журнале не печатается ряд страниц.

Front Cover: A Chinese Long March 2 rocket is launched from the Shuang Cheng Xi launch site and places a photographic satellite, China 17, in orbit. The launch, which took place on October 21, 1985, was part of China's modest but progressively developing space programme which is the subject of a special feature beginning on p.62.



UK Delegation Visits Beijing and Shanghai

In 1985 Mr. Geoffery Pattie, Minister of State for Information Technology at the Department of Trade and Industry, signed an Memorandum of Understanding with the Ministry of Astronautics of the People's Republic of China in which it was agreed to co-operate in space science and technology.

Mr. Roy Gibson, Director General of the BNSC, is welcomed by senior representatives of the Shanghai Institute of Satellite Engineering during the visit of the UK party to Shanghai.

Preparation of the Chinese CZ-3 vehicle for the launch of a communications satellite from the Xichang launch site which became operational in 1984. CZ is an abbreviation for "Chang Zheng" – Long March.

Since then the UK has received a number of visitors from the PRC who have been shown what is going on in the British aerospace industry and in Government establishments. The aim has been to identify a number of candidate areas which seem to be suitable for co-operation between the two countries.

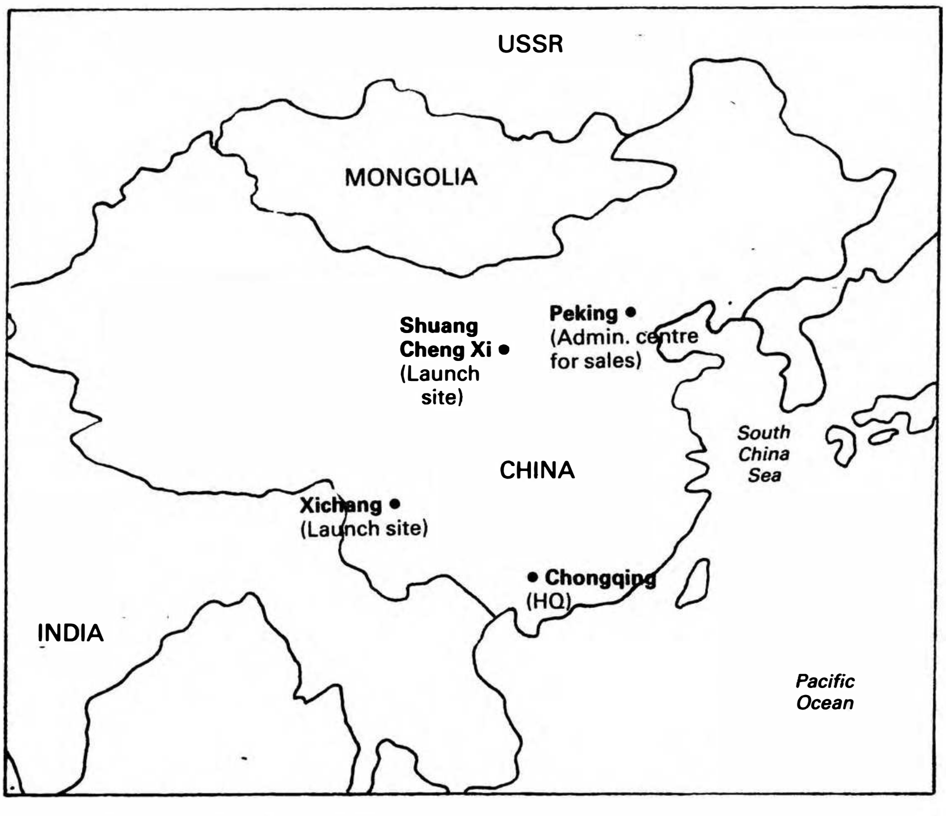
This led to an invitation for BNSC to visit the PRC in December last year to take part in the first formal joint meeting under the cooperative agreement. The delegation, headed by Roy Gibson, Director General of the BNSC, consisted of senior representatives from various parts of the BNSC, plus two representatives from industry; Mr. Mike Painter of Marconi Space Systems and Mr. Pierre Diederich of Racal Decca Advanced Systems.

The UK party was in China from December 1-10 and visited Beijing and Shanghai; the planned visit to the Long March launch site in Xichang was thwarted by three days of fog at Chengdu, and had to be postponed until the next visit – probably in June 1987.

The delegation, in addition to meeting the Minister of Astronautics, Mr. Li Xu'E and his deputy, Professor Sun Jia Dong, was received in the great Hall of the People by Professor Song Jian, Science & Technology Councillor. Professor Song was very positive about the prospects of identifying space projects on which PRC and the UK could work together.

In a meeting with the Chinese Academy of Science, Mr. Gibson transmitted the fraternal greetings of the British Interplanetary Society and urged the Chinese societies to ensure a significant PRC participation in the 1987 IAF Congress to be held in Brighton.

It was agreed to follow up the discussions on the various candidate areas and to take stock of progress in June.



CHINA REPORT p.62

CORRESPONDENCE

Current interest in Soviet space activity is shown by the following selection of readers' letters:

Soviet Space Activity

Sir, Bart Hendrickx (***Spaceflight*** January 1987, p.16) states that "the Soviets strictly follow their mysterious two month interval between visiting trips". Why the mystery? It was explained in my 1979 ***Spaceflight*** paper [1]. Basically, the orbit of Salyut (or now, Mir) precessed such that the nodes circled the celestial equator every two months: neglecting minor seasonal variations, the lighting conditions for launch and recovery repeat every two months. The visiting missions were timed so that they would return during the landing windows which last for 5-8 days each two months period, and they were launched a few days before a landing window opened.

David Anderman's comments about the masses of various Soviet spacecraft and rockets echos my own work completed in 1983 [2]. He discusses the Meteor flights in particular, trying to equate the flights with the launch vehicles. Perhaps the following analysis based only upon the orbits and Soviet cumulative masses may be interesting.

The original Meteor-1 series of missions can be split into two groups: eight flights had orbital periods of 97-98 minutes and 20 had periods of 102.4 minutes. All the Meteor-2 flights flew in 102.4 minute orbits. The Soviets originally said that the Meteor satellites used the "Vostok" (SL-3) booster, but this was before the high orbit missions began. The high orbit Meteor-2 missions are all credited to the Soyuz (SL-4) booster, as are the retrograde orbit Meteor-Priroda satellites.

The orbital stage of the SL-3 booster is about 1.45 tonnes and that for Soyuz about 2.35 tonnes. Using these masses suggests that of the 42 launches in the Meteor-1/Meteor-2/Meteor-Priroda series, 15 used the SL-3 and 27 the SL-4. This would give rocket masses of 73.45 tonnes for the 1980 cumulative total (vs Glushko's 75.22 tonnes) and 85.20 tonnes for the 1984 cumulative total (vs Glushko's 84.22 tonnes). These figures are not in perfect agreement, but then again a detailed study of Glushko's data shows that his data includes arithmetical errors.

Considering the SL-3 launch of Intercosmos/Bulgaria-1300, the payload was placed in an orbit somewhat lower than that for the Meteor-2 satellites, and the payload uses a Meteor "bus" but without all the meteorological equipment. Possibly the SL-3 could not lift a Meteor-2 class payload to the normal high orbit? It seems probable that the Meteor-2 and Meteor-3 launches are now made using the Scarp-derived SL-14 booster, although the change should not significantly alter the numerical data quoted above.

As a finale, the following data is implied by Glushko's tables:-

Salyut 7 mass	19.92 tonnes
Salyut 7 rocket mass	4.4 tonnes
Salyut 6 mass (as quoted)	19824 kg
Salyut 1-6 rocket masses	5.61 tonnes
Proton 4 orbital stage	5.6 tonnes (= Salyut stage)
Proton 1-3 orbital stages	13.18 tonnes

On Proton 4 the third stage of the booster went into orbit, and on Protons 1-3 it was the second stage which was orbital.

P.S. CLARK
London

References

1. Phillip S. Clark, "Soyuz Missions to Salyut Stations", *Spaceflight* vol 21, pp 259-263 (1979).
2. Phillip S. Clark, "Soviet Spacecraft Masses For Earth Orbital Programmes", *JBIS*, vol 38, pp. 19-24 (1985).

Proton Launch Rates

Sir, The Soviet space organisation Glavkosmos, as part of its marketing effort for the Proton launcher, recently revealed some details about the operational history of this long-mysterious space vehicle [1]. The version of the Proton being marketed, the D-1-E (SL-12), was described as a four-stage launcher, with a capability to send a 1500 kilogram payload to geosynchronous orbit. The Soviets reported that there are two Proton launch pads at Baikonur, located about 600 metres apart.

Most importantly, the Soviets produced a chart listing the numbers of SL-12's launched successfully (and unsuccessfully!) since the early 1970's. Some interesting conclusions can be drawn from this data, presented in Table 1. The 1970 launch of Cosmos 382 can now be attributed to the SL-12, rather than some unusual variant of the Proton. More recently, all the Cosmos 1603-class satellites apparently have been orbited by the SL-12, with the possible exception of Cosmos 1714. This seems to contradict reports that these spacecraft may have been launched by a new Soviet medium-lift booster.

The Soviets also reported that construction of the MIR space station will take another five years, with the first expansion module, an astrophysics lab, to be orbited before mid-1987 [2].

DAVID ANDERMAN
California

REFERENCES

1. "Soviets Offer Commercial Leases of Gorizont Communications Satellites", Aviation Week, December 8, 1986, p. 25.
2. "Mir Today, Mars Tomorrow", Aerospace America, December 1986, pp. 6-8.

Table. 1: Proton Launch Rates 1970-1985.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
SL-12	4	5	1	5	4	4	3	2	4	5	5	6	7	11	13	9	88
SL-13	0	1	0	2	2	0	2	2	1	1	0	1	1	1	0	2	16
Total	4	6	1	7	6	4	5	4	5	6	5	7	8	12	13	11	104

Notes

The SL-12 data is supplied by *Glavkosmos*, as reported by Aviation Week magazine, December 8, 1986, page 25.
The SL-13 data, and overall numbers of Proton launches are derived from several sources:
The RAE Table of Earth Satellites, 1983-1985, Royal Aircraft Establishment, January 1986, Farnborough, England.
The Soviet Year in Space – 1984, Nicholas L. Johnson, Teledyne Brown Engineering, Colorado Springs.
The Soviet Year in Space – 1985, Nicholas L. Johnson, Teledyne Brown Engineering, Colorado Springs.
"Les Champs de Tir Dans Le Monde", – Aeronautique et L'Astronautique, 1982 Number 4, pp. 65-69.
"Soviet Launch Vehicles – An Overview", P.S. Clark, *JBIS* 1982, pp. 51-58.

CORRESPONDENCE

Soviet Booster Failures

Sir, Could you tell me if the Soviet Union has successfully launched its G1 booster rocket, since the three launch failures ending 1972?

Hoping you can help me in any way.

R. ALWAY
Gloucester, UK

Ed. *A response to Mr. Alway's enquiry has been provided by Phillip S. Clark as follows:*

The Type-G vehicle is credited with three orbital attempts: the first exploded on the pad on 3-4 July 1969 and the second two were launched and lost on 23-24 June 1971 and 24 November 1972. In 1975 there were some reports that new Type-G boosters were on the pads in the summer months, but if anything appeared on the launch pads they were only facilities test vehicles, not flight-rated boosters.

After the 1972 failure, the original Type-G booster (designated SL-15 by the US Department of Defense) was scrapped, and in the mid-1970s work began on a new family of launch vehicles. The Medium Lift SL-16 booster (15-20 tonne orbital capacity) Heavy Lift SL-W booster (150-280 tonnes to Earth orbit, depending upon configuration) has been tested on the pad, but there was no launch attempt to the end of 1986: the SL-16 first stage is probably used as strap-ons for the SL-W vehicle. The SL-W can be used either as an unmanned booster or it can carry the large Soviet Shuttle orbiter into space (first flight due in 1988?).

Training Errors

Sir, In Soviet Scene (***Spaceflight***, December 1986, p. 424-425), French cosmonauts Jean-Loup Chrétien and Michel Toignini were reported to have begun training for the 1988 Soviet-French Mir mission in September 1986. However, the Soviets announced that the two "spationauts" only arrived in Moscow on November 15 and started training at the Gagarin Cosmonaut Training Centre several days later.

Writing also on the July 16 return of the Soyuz T-15 spacecraft, Neville Kidger says the command for retrofire was given at 12.05 GMT, which would appear to be inconsistent with the (correct) entry interface and touchdown times of 12.11 and 12.34 respectively. Soyuz spacecraft fire their deorbit engines about fifty minutes before landing and to the best of my knowledge Soyuz T-15 was no exception to that rule. The 207 second burn got underway at approximately 11.44, as can be deduced from the live reports on the spacecraft's return broadcast by the Soviet "Mayak" radio station. The vehicle was flying over the South Atlantic (close to South America) at the time and communications were being relayed through the tracking ship "Georgiy Dobrovolskiy", said space reporter Sergei Zehelznyak, who was covering the Soyuz T-15 landing for Mayak from Mission Control in Kalinin.

BART HENDRICKX
Belgium

Canadian Takes Second Place

Sir, Regarding Philip Chien's article "The Mapleleaf In Space" (***Spaceflight*** January 1987, p.24) I would just like to point out that the first Commonwealth subject to go into space was not the Canadian astronaut Marc Garneau – launched on October 5, 1984 – but the Indian astronaut Sqn Ldr. Rakesh Sharma who flew aboard Soyuz T-11 on April 3, 1984.

T. STRATHAM
Watford, Herts

Shuttle Safety

Sir, I was very interested to read the article New Solid Rocket Motor Design in "Up-date USA" ***Spaceflight***, November 1986, p.377-8. I appreciate this will offer several safety features which will help to prevent future Shuttle accidents. I understand that the Shuttle programme is currently reviewing astronaut safety in the event of early Shuttle aborts. In all my reading I have not come across a discussion of procedure in the event of failure of one SRB to fire. Presumably launch would not be possible because of the asymmetry produced. Could astronauts be rescued from the Shuttle cockpit on the pad? Also, could a Shuttle remain on the pad until the SRB had exhausted the solid fuel supply?

J.R. MURPHY
Gloucester, UK

Crew Escape Systems

Sir, With regard to the redesign of the Shuttle Orbiter escape systems (***Spaceflight*** January 1987, p.13), could someone please comment on this suggestion?

One small solid rocket pod mounted on each wingtip. In the event of an emergency during the initial ascent mode these could, with the ET/SRB separation, pull the Orbiter away from the "stack" preventing the possible "hang up" of the Orbiter as highlighted during the report of 51L. This would at least get the Orbiter away from danger and the chance of a return to launch site.

During a normal ascent the pods would be separated at the same time as the external tank. An explosive bolt would separate a retaining strap from the Orbiter wingtip with a drogue chute deploying shortly after. This would deploy the main chute with the recovery beacon coming on at the same time.

J.S. ANDERSON
Liverpool

★ ★ ★

6 June 1987, 10 am to 5 pm *Symposium*

THE SOVIET SPACE PROGRAMME

Offers of papers are invited. Society members with a special interest in the Soviet Space Programme are invited to attend the symposium to be held at the BIS HQ, London.

☆ ☆ ☆

A registration fee of £5.00 is payable. Forms are available from the Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose a stamped addressed envelope.

CORRESPONDENCE

Armstrong on the Moon

Sir, It was with interest that I read John H. Fadum's letter (***Spaceflight*** December 1986, p.417) concerning photography of Neil Armstrong on the lunar surface during the Apollo 11 mission. I have recently been carrying out research on this very subject.

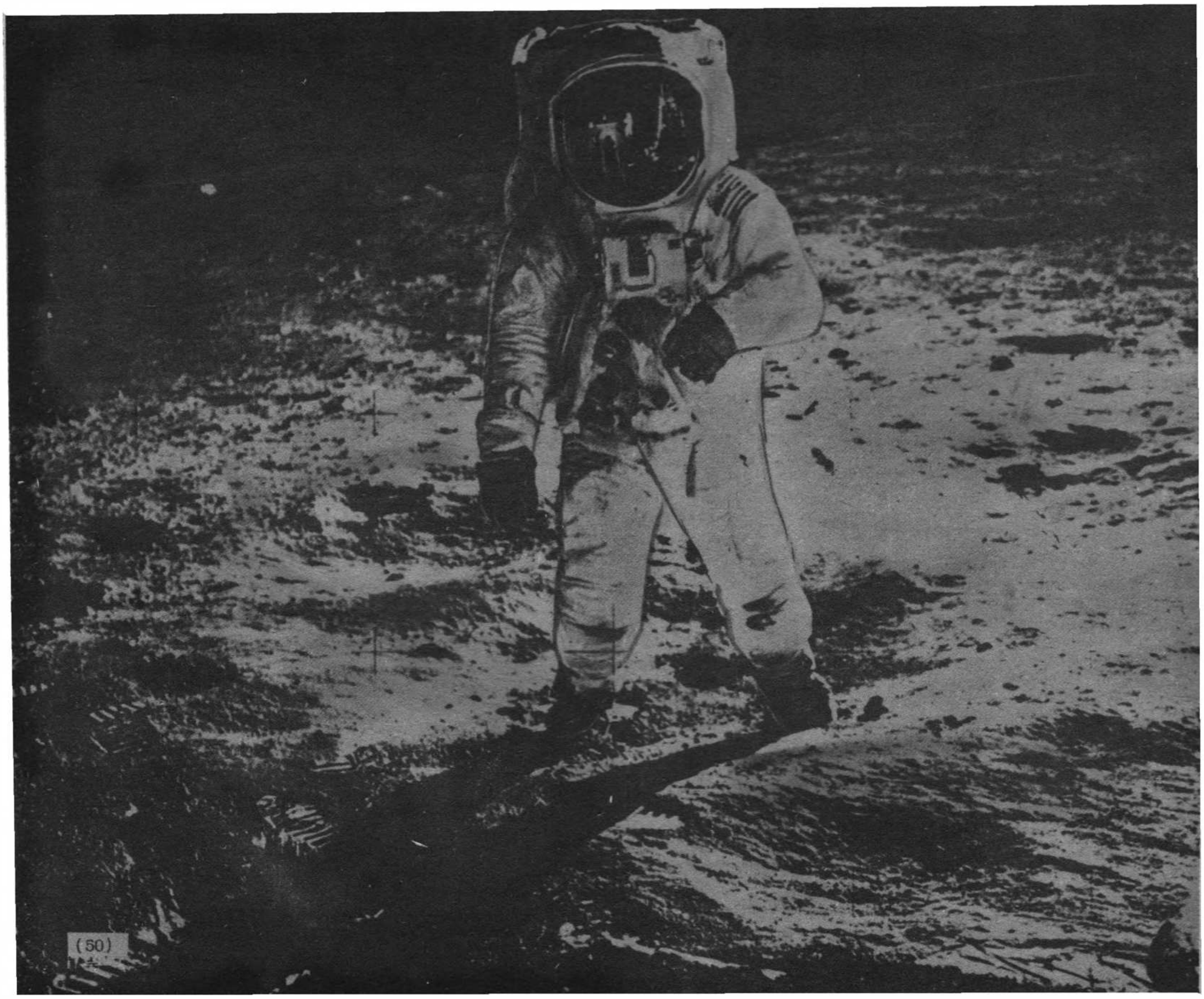
It has always puzzled me as to why no one provided for a Hasselblad photograph of the Apollo 11 commander on the lunar surface – especially considering the historical significance of the event. According to the flight plan, Armstrong was scheduled to photograph Aldrin on two separate occasions during the moonwalk but the reverse was not true, despite the fact that Aldrin did use the Hasselblad to take a series of photographs. Armstrong, as we know, did not follow the flight plan rigorously and took many photographs of Aldrin. Aldrin, it seems, kept rigidly to the plan and made no effort to photograph Armstrong. The fact that the flight plan did not allow for a photograph of Armstrong seems a curious omission on the part of the flight planners.

It would not have been difficult for Aldrin to photograph his commander on the lunar surface during the time he had the camera. One NASA/JSC source I have contacted has stated that the reason Aldrin did not photograph Armstrong was related to a problem which occurred some months before the mission. The original plan for the moonwalk required Aldrin to be the first onto the surface with Armstrong following. Armstrong, as commander, felt that he should be the first. NASA agreed and so Aldrin became the second man on the Moon.

Armstrong, being the private person he is, was probably not overly concerned with having photographs of himself taken by Aldrin while on the Moon. However, Armstrong has stated on at least two occasions which I know of, that Aldrin took a number of photographs, including at least one which shows himself in the background. Armstrong has been unable to give the identification number of the print in question. To date, Neil Armstrong is the only person I know of who believes that a Hasselblad photograph of himself on the lunar surface exists. Richard Underwood, who processed the Apollo 11 Hasselblad film is adamant that no such photograph of Armstrong exists. Could Armstrong be thinking of the famous view of Aldrin with the Apollo 11 commander reflected in the lunar module pilot's visor? I would be interested to hear from anyone who might be able to shed some light on this matter.

KEITH T. WILSON
Strathclyde

Edwin 'Buzz' Aldrin stands among the 'magnificent desolation' of the lunar landscape with Armstrong and Eagle reflected in his vizor. This is perhaps the most frequently reproduced photograph from all the Apollo 11 surface pictures, but no comparable photograph is available of Armstrong, the first man on the Moon.



INTERNATIONAL SPACE REPORT

A monthly review of space news and events

SPACE STATION: Role of ELVs Assessed

A NASA team has recommended against the use of Expendable Launch Vehicles (ELVs), both existing and those due to come into operation, for Space Station construction.

The potential for ELVs was examined as part of a major review by NASA during 1986 and analysis showed that schedules could be improved by between four and nine months if Space Shuttle missions were supplemented by ELVs.

However, ELVs would increase the amount of Extra Vehicular Activity required during the first four Station-dedicated Shuttle assembly flights by between 10 and 40 per cent, would require basing an Orbital Manoeuvring Vehicle at the Station throughout the assembly phase to control, boost and re-boost passive structural elements, and could impact the weight and design of Space Station components because of the higher dynamic forces associated with ELVs.

The analysis also demonstrated that the accelerated assembly schedule was dependent upon retaining the planned Shuttle flight rate to support assembly of the Station and required the availability of as many as three Titan 4 launches during the first two years of Station assembly activity.

NASA's Space Station Office has concluded that the substantial technical and programmatic uncertainties, the increased operational risks associated with the use of ELVs for the initial assembly phase and the increase in costs required to compensate for these uncertanties and risks far out weighed the marginal schedule benefits to the Space Station programme.

The programme will, however, continue to retain the option of using an expendable launch vehicle to launch the polar platform, one of two unmanned free-flyers that are components of the Space Station. The study group concluded an ELV could be used to launch the high inclination platform in the event of a delayed reactivation of the Shuttle launch site at Vandenberg Air Force Base.

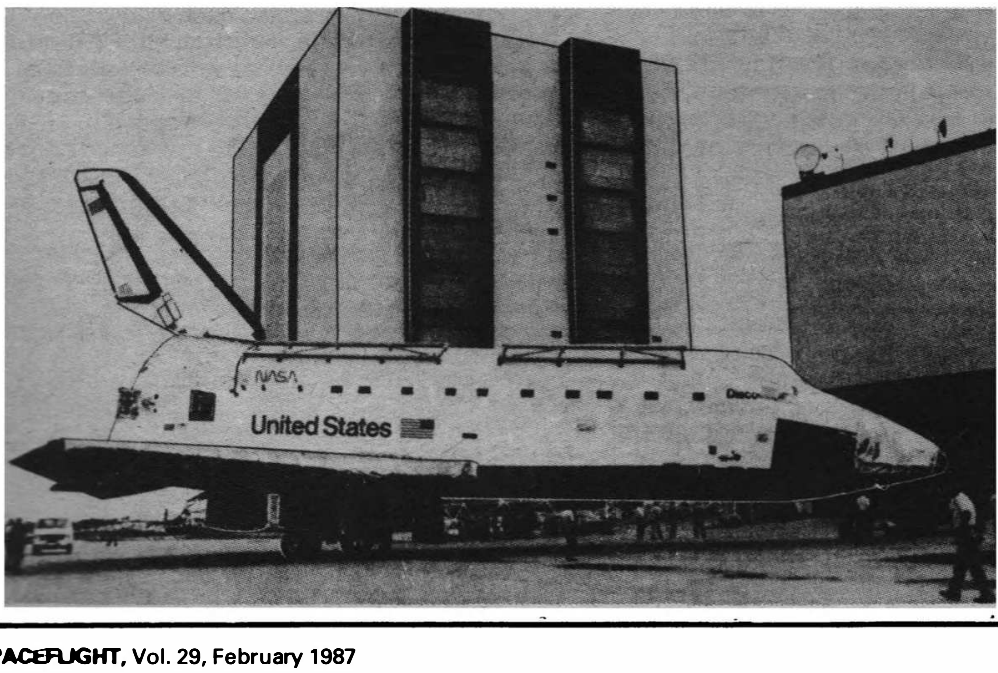
NASA's current launch manifest allows for the first Space Station – related Shuttle flight in early 1993, followed by a further four missions before the end of the year. In 1994 another seven Shuttle flights for Space Station construction are planned.

NEXT GENERATION SATELLITE

Spar Aerospace has signed a $200 million contract with Telesat Canada for two Anik E communications satellites which will be the largest and most powerful dual-band satellites to be placed in commercial service for North America.

The satellites will take three years to build and are scheduled for launch in 1990.

Spar was also prime contractor for Telesat's two Anik D communications satellites. Most recently, the company built two satellites for Brazil, the first satellite communications system for Latin America, (see page 88).



First Flight Work

The Orbiter Discovery, scheduled to be used for the first flight when Shuttle operations resume in 1988, was rolled into the Orbiter Processing Facility recently at KSC as a first step in the preparations for launch.

INTERNATIONAL SPACE REPORT

Veteran Crew for Next Shuttle Flight

The flight crew for Shuttle mission 26, scheduled for launch on February 18, 1988, was announced by Rear Admiral Richard H. Truly, NASA Associate Administrator for Space Flight, at the beginning of last month (January).

The mission will be commanded by Frederick H. Hauck (Captain, USN), currently assigned as Acting Associate Administrator for External Relations, NASA Headquarters, Washington. Hauck previously commanded mission 51A in November 1984 and served as pilot on STS-7 in June 1983. He will resume his astronaut duties during the first week of February.

Richard O. Covey (Lt. Col., USAF) will be the pilot on this mission. Covey served as pilot on flight 51I in August 1985.

Mission specialists for the mission will be John M. Lounge, who flew as a mission specialist on flight 51I; George D. Nelson, who served as a mission specialist on flights 41C in April 1984 and 61C in January 1986; and David C. Hilmers (Major, USMC), who flew as a mission specialist on flight 51J in October 1985.

In announcing the crew, Adm. Truly said: "The naming of the crew for the next flight is a major event in the process of returning the Shuttle to flight. I am particularly pleased to assemble a group of such experienced individuals led by one of our senior space flight veterans and I am very proud of them."

Frederick H. Hauk

The primary payload for the four day mission is the Tracking and Data Relay Satellite (TDRS), a NASA communications satellite.

FLIGHTS TO CHECK OXIDATION

Unique features of the Space Shuttle have brought to light two unexpected phenomena that affect spacecraft orbiting at low orbital heights:

1. The erosion of materials due to reactions with atomic oxygen, which is the main atmospheric gas at these heights.

2. The indication of a glowing region near the surface of some Shuttle materials exposed to the ram environment. Rapid enhancements of these surface glows are found to occur at the time of Orbiter thruster firings.

It became obvious with the first Shuttle flight that various materials exposed to the environment had undergone changes, such as loss of surface gloss, an apparent 'aging' of painted surfaces as well as a reduction of film thickness, i.e. a loss of material.

On subsequent flights, the effects of the space environment on a greater variety of exposed materials have been observed. Tests with protective coatings on various main materials were carried out on earlier Shuttle flights and substantial reductions, by 10^{-2} to 10^{-3}, in the loss of material were achieved. More sophisticated experiments are currently under construction for introduction when Shuttle flights resume.

The glow phonomenon was first recorded in the Shuttle programme when night-time photographs, taken by the crew of STS-3, revealed a reddish glow originating on and above vehicle surfaces exposed to the ram direction. The design of the Orbiter payload bay to allow complete astronaut observation has allowed greater viewing of surfaces exposed to the ram environment and resulted in greater awareness of the glow than with previous manned missions.

METEOROLOGY OPERATIONS

Eumetsat, an organisation which represents the national meteorological interests of 16 European states, is to take over the operation of European weather satellites and assume responsibility for the Meteosat Operational Satellites programme.

The MOS programme, developed by the European Space Agency (ESA), is due to operate until the end of 1995 with the launching of three new satellites over the next four years.

These satellites will replace the two pre-operational Meteosat satellites which were launched in 1977 and 1981. The latter, with an expected life of three years, is still functioning with exceptional reliability.

Whilst the construction, launch, control in orbit and data processing of the satellites will continue to be an ESA responsibility, Eumetsat will look after the programme's funding and all external relations.

Eumetsat was formed in June last year and its headquarters are in Darmstadt, Germany. The European Space Agency's Operations Centre (ESOC) is also at Darmstadt.

The member states of Eumetsat are: Belgium, Denmark, Federal Republic of Germany, Finland, France, Greece, Ireland, Italy, Norway, Portugal, Spain, Sweden, Switzerland, the Netherlands, Turkey and the United Kingdom.

JAPANESE X-RAY SATELLITE

A science payload to study X-ray emissions from deep space is due to be launched by Japan at the beginning of this month (February).

Astro-C, an 924 lb satellite, will be launched from the Tanegashima site by a Nissan-built vehicle.

INTERNATIONAL SPACE REPORT

PAYLOAD SWITCHED TO DELTA

The Cosmic Background Explorer (COBE) satellite is to be launched on a Delta expendable rocket rather than the Space Shuttle in an effort to reduce the backlog of science payloads that cannot be accommodated by the Shuttle.

COBE will be launched into a 560 mile, Sun-synchronous orbit from Vandenberg Air Force Base, California, in early 1989.

Carrying three scientific instruments, COBE is designed to study background radiation from the "Big Bang", a theory which explains the expansion of the universe by a primeval explosion 15 billion years ago.

Originally scheduled for deployment from the Space Shuttle in July 1988, COBE is one of several science payloads awaiting launch as a result of the Challenger accident.

The switch from Shuttle to Delta will mean a reduction in the weight of COBE from 10,500 pounds to 5,000 pounds and reduction in size from 15 feet to eight feet in diameter.

Scaling down the spacecraft will require a redesign of the primary structure, a reconfiguration of its solar arrays, thermal shield and the differential microwave radiometer receiver.

OVEN READY FOR BREAD TEST

The oven designed to bake the first bread in space is ready for launch as soon as Shuttle flights resume. Spar, Monarch Flour and Telesat Canada are co-sponsors of a self-contained experiment suggested by ten Canadians. The oven was designed and built by Telesat Canada and is being stored in a clean room at their Ottawa facility.

The experiment is part of a low-cost NASA programme for experiment packages, known as Getaway Specials, mounted in the Space Shuttle cargo bay. The bread experiment will test the reaction of yeast and other ingredients in the weightlessness of space.

NEW ZEALAND AUSSAT DEAL

New Zealand has entered the domestic telecommunications satellite business with the signing of a contract allotting it ten percent of the transponder capacity on Australia's Aussat-3 satellite, due to be lofted by a European Ariane launcher in March, ***writes David Maclennan.***

The five-year contract was signed in Sydney, Australia, on November 25, 1986 by Derek Rose, assistant director-general of the New Zealand Post Office (NZPO) and Aussat managing director Graham Gosewinckel.

The capacity to be used by NZPO will be for distribution of domestic services within New Zealand, including television programmes, video-conferencing and high-speed data and facsimile services, as well as for improving telecommunications services to remote areas of New Zealand and some offshore territories.

NZPO will use all of one of Aussat-3's 30w transponders for television distribution, and part of a lower powered 12w transponder for other telecommunication services.

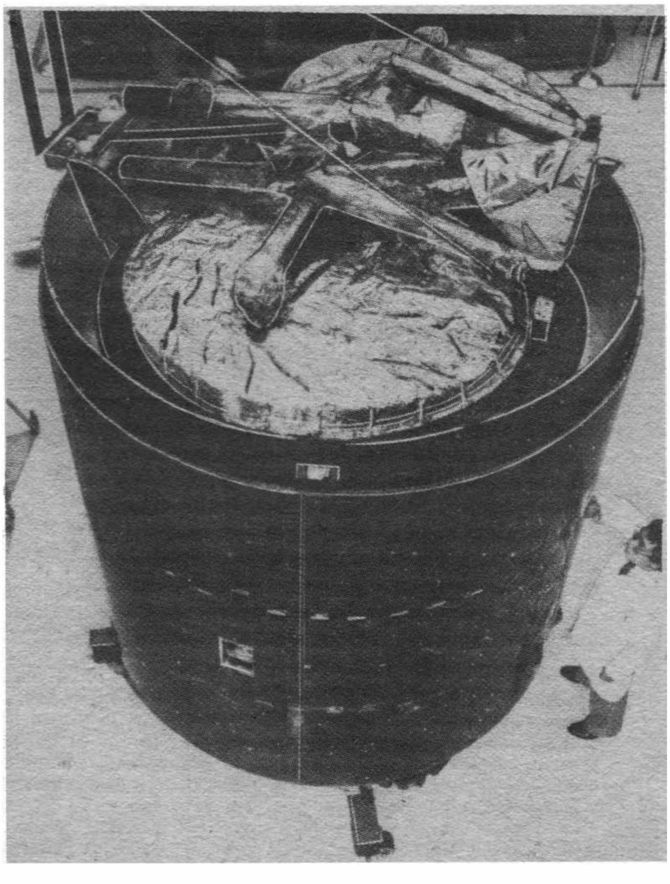
According to Rose, NZPO plans to provide terminals at a nominal cost to allow New Zealanders to gain experience with the new service. Among those who could be interested are banks wanting to devleop electronic banking services, though as yet no formal contracts with New Zealand customers have been signed.

New Zealand's Postmaster-General Jonathan Hunt said that the new service provides New Zealand with an exciting opportunity to gain first hand experience in the use of Earth stations for a wide variety of services.

"The experience will stand us in good stead for future projects, such as joint venture design and launch of purpose-built satellites to provide an even wider range of service," he added, referring to NZPO discussions with Aussat on the design and development of a second-generation Aussat system for the early 1990s.

Aussat-3 is scheduled for launch next month (March) aboard an Ariane 3. It will be placed in geostationary orbit over the equator at 164 degrees east.

Australia's Aussat communications satellite uses a unique three-reflector antenna system to form its regional and national transmit and receive beams. In its launch ready position with the antenna folded down, Aussat, built by the Space and Communications Group of Hughes Aircraft Company, is only nine feet high. On orbit, the antenna is erected and its telescoping solar array depolyed to stretch Aussat to nearly 22 feet in height. *Hughes*



SATELLITE DIGEST – 199

Robert D. Christy

Continued from the January, 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1783, 1986-75A, 16993.
Launched: 1300, 3 October 1986 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Apparently intended to be part of the USSR's ballistic missile early warning system, but it was left in a useless orbit due to an early shut-down of the final rocket stage.
Orbit: 598 x 20058 km, 358.15 min, 62.77 deg.

CHINA 19, 1986-76A, 17001
Launched: 0538, 6 October 1986 from Shuang Cheng Tse by Long March 2.
Spacecraft data: not available
Mission: Earth resources photography, a capsule containing film and, possibly, the cameras was recovered on 11 October.
Orbit: 172 x 387 km, 90.07 min, 56.97 deg.

COSMOS 1784, 1986-77A, 17003
Launched: 0740, 6 October 1986 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance, re-entered after 36 days.
Orbit: 211 x 281 km, 89.43 min, 64.76 deg, manoeuvrable.

COSMOS 1785, 1986-78A, 17031
Launched: 0930, 15 October 1986 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustement motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stablisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 596 x 39299 km, 708.49 min, 63.03 deg, then raised to 595 x 39740 km, 717.39 min, 63.03 deg to ensure daily repeats of the ground track.

MOLNIYA-3 (30), 1986-79A, 17038
Launched: 0850, 20 October 1986 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 626 x 38977 km, 702.60 min, 62.84 deg then raised to 625 x 39724 km 717.67 min, 62.87 deg to ensure daily repeats of the ground track.

COSMOS 1786, 1986-80A, 17042
Launched: 0800, 22 October 1986 from Tyuratam, possibly by A-2.
Spacecraft data: Not available.
Mission: Not available.
Orbit: 191 x 2564 km, 113.29 min, 64.89 deg.

COSMOS 1787, 1986-81A, 17044
Launched: 0900, 22 October 1986 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass was between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 13 days.
Orbit: 230 x 281 km, 89.65 min, 69.99 deg.

RADUGA 19, 1986-82A, 17046
Launched: 1543, 25 October 1986 from Tyuratam by D-1-e.
Spacecraft data: Probably similar to the Gorizont satellites, being a stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links within the USSR.
Orbit: Geosynchronous above 45 deg east longitude.

COSMOS 1788, 1986-83A, 17050
Launched: 1242, 27 October 1986 from Plesetsk, by C-1.
Spacecraft data: Possibly a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Electronic intelligence gathering.
Orbit: 468 x 517 km, 94.47 min, 65.84 deg.

COSMOS 1789, 1986-84A, 17054
Launched: 0800, 31 October 1986 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m, diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 322 x 342 km, 91.23 min, 82.58 deg.

UPDATES

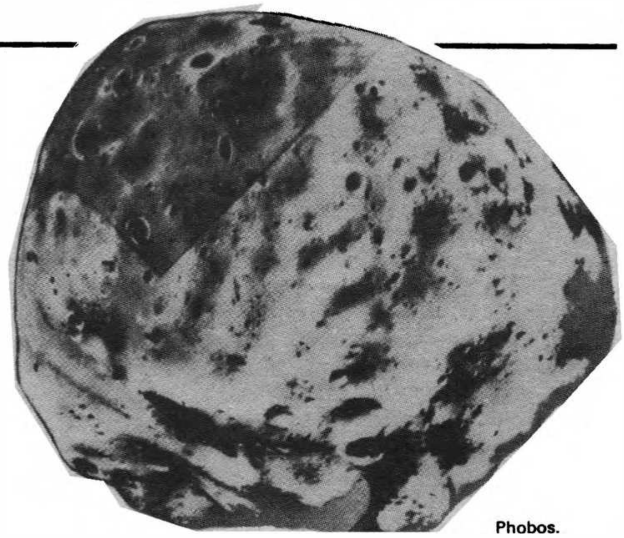
1962 Beta-Phi 1, TRANSIT 5A, decayed on 25 September 1986.

1986-55A, COSMOS 1766 is a remote sensing, oceanographic satellite.

SOVIET SCENE

UK Scientists to Join Phobos Mission

The recent visit to the Soviet Union by a delegation from the British National Space Centre (BNSC) resulted in an invitation from Academician Roald Sagdeyev, Director of the Space Research Institute, for the BNSC to nominate up to three interdisciplinary scientist from the UK to take part in the Soviet Phobos space mission.


Phobos.

The Mission

The phobos mission (***Spaceflight*** March 1986, p.113, Sep./Oct. 1986, p.348) is in many senses a follow-up to the successful Vega spacecraft sent to Venus and Comet Halley. As with the Vega mission, the foreign involvement in the programme is large. There are hardware contributions from Austria, ESA, Finland, France, Sweden, Switzerland, West Germany, as well as the other Interkosmos members Bulgaria, Czechoslovakia, East Germany, Hungary.

The spacecraft, to be launched in mid-1988, will be three axis stabilised. There is a 200 day cruise phase before its insertion into orbit about Mars, initially into a 4200 x 79000 km three day period elliptical orbit. After 25 days the periapsis is then raised and it is planned to take up a 9700 x 79000 km orbit for 30 days.

Roald Sagdeyev.

The Phobos encounter is achieved by first taking up a circular 9700 km radius eight hour period orbit and then dropping to a circular 9400 km (7.6 hour) orbit taking it to within 30 km of Phobos. The spacecraft is then manoeuvred to flyby Phobos, close enough to remain within 50 m of the moon's surface for about 15 minutes.

The design currently includes some 30 instruments (***Spaceflight***, March 1986, p.113). However, there is at present a payload mass excess of 100 kg, a problem that has yet to be resolved.

Scientific Programme

The Phobos scientific programme is split into four sub-areas: Solar; Solar-planetary interactions; Mars; and Phobos studies. It is proposed to nominate UK scientists to three of these sections.

The BNSC envisages that an interdisciplinary scientist (IDS) will be attached to one section within which it would be up to him/her to work with the various instrument teams. The scientists eventually selected will attend science workshops prior to launch and will also be expected to be particularly active once data starts to arrive.

The BNSC has invited proposals from prospective interdisciplinary scientists who should submit a brief outline of the experience of the applicant and the specific role that he/she could play in the project. The IDSs will be required to be of high international standing and preferably have some past experience of working with Soviet scientists.

Outstanding proposals should be submitted to Jane Williams at the BNSC to arrive before February 13, 1987. They should not exceed three pages in length. The proposals will be reviewed and announcements made in April 1987.

Interdisciplinary scientists will be eligible to apply for research grants, to be awarded under normal SERC grant conditions, to support project related activities.

SOVIET SCENE

Launch Offer Includes Security Guarantee

The Soviet Union has reinforced its offer to launch satellites from the West (*Spaceflight*, December 1986, p.424) on a commercial basis by agreeing to exempt payloads from customs and other official inspections.

The prospect of technically sensitive hardware entering the Soviet Union has so far prevented acceptance by western countries, who would otherwise have found the offer financially very attractive at a time when western launch schedules have suffered a major setback through launch vehicle failures.

Inmarsat, the international organisation for maintaining satellite communications with ships at sea, has so far been prevented from taking up the Soviet launch offer by US refusal to allow US satellite equipment to go to a Soviet launch site.

Recent Soviet efforts to overcome such objections have included an interview by Soviet Prime Minister Nikolai Ryzhkov to the *Tass* news agency.

"Our proposal for launches of foreign spacecraft by Soviet carriers has been prompted by a desire to advance space exploration and use Soviet rockets and other space technology, which have repeatedly demonstrated their high standards and dependability, efficiently for these purposes," Mr. Ryzhkov said.

"As it enters the international market of space technology and services, the Soviet Union, of course, must reckon with the laws of this market. It is only natural that we expect to make some gains.

"At the same time, we shall be seeking to make the launch terms mutually advantageous, both to us and to clients. When orbiting spacecraft for developing countries, the Soviet Union is prepared to grant them substantial discounts. Soviet financial organisations can also insure the payloads."

Mr. Ryzhkov said that Soviet state agencies will give clients the necessary guarantees of safety for their spacecraft throughout their stay in the territory of the USSR – from the moment they cross the border until lift-off.

He added: "We are prepared to exempt the equipment intended for a space launch from inspection by the customs and permit its passage across the territory of the USSR to the cosmodrome in a sealed container, if this is more convenient for clients. Foreign specialists will be able to escort their spacecraft and watch it being transported and installed on a carrier rocket."

SUMMER LAUNCH DATE

The Soviet-Syrian space mission is scheduled to begin on the morning of July 22, 1987, according to Valery Ryumin, head of the joint mission. The international crew will be welcomed on board Mir by Soviet cosmonauts, due to dock with the orbital station in early 1987.

The main crew includes Flight Commander Alexander Victorenko, Flight Engineer Alexander Alexandrov, and Mohammed Fares, a citizen of the Syrian Arab Republic (SAR). The stand-by crew is commanded by Anatoli Solovyov and includes Flight Engineer Victor Savinykh and Munir Habib of the SAR.

Soviet launch dates are only normally announced in advance when nationals from foreign countries are members of the crew.

BULGARIAN COSMONAUTS

The two Bulgarian pilots, one of whom will take part in a joint mission with Soviet cosmonauts to Mir in 1988, have been named.

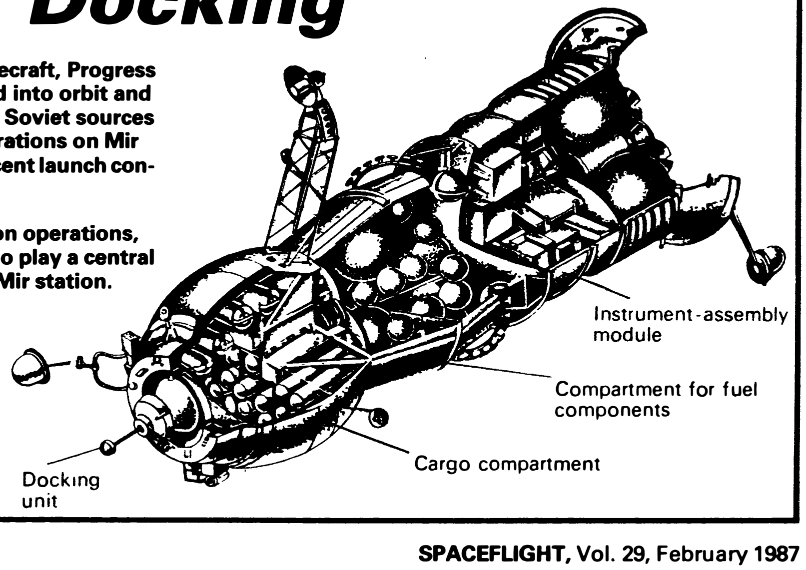
They are Alexander Alexandrov, back-up to George Ivanov, the first Bulgarian cosmonaut in 1979, and Krasimir Stoyanov. Alexandrov has the same name as the Soviet cosmonaut in the crew due for launch this summer.

Mir Station Docking

On January 18 a Soviet unmanned spacecraft, Progress 27, carrying fuel and supplies was launched into orbit and docked automatically with the Mir station. Soviet sources had previously indicated that manned operations on Mir would be resuming in early 1987 and the recent launch confirms the start of the Mir 1987 programme.

As with the previous Salyut space station operations, Progress cargo transporters are expected to play a central role in the main training operations of the Mir station.

An additional role for a Progress space craft is that of a 'space dustbin'. All waste materials are loaded into the Progress which is then propelled from the station into a re-entry orbit into the atmosphere where it burns up. The principal features of a Progress cargo spacecraft are shown opposite.



EUROPEAN RENDEZVOUS

Tests Delay Ariane Launch to Spring

Prof. R. Lüst (ESA Director General), Mr. F. d'Allest (Arianespace chairman) and Mr. Sollier (S.E.P. chairman) at a press conference in Bordeaux to discuss the resumption of Ariane flights.

The resumption of Ariane flights following the launch failure last May is not now expected before the middle of April this year.

Mission V19, which will carry two communications satellites (ECS 4 and Aussat K3 or G STAR III), was scheduled for launch this month (February) as the first of six planned flights during 1987, including the first Ariane 4.

The last successful Ariane launch was on March 28, 1986 when United States and Brazilian communications satellites were placed into orbit. Subsequently, on May 30, an Ariane 2 version of the launcher and its Intelsat communications satellite were destroyed after a failure in the third stage ignition.

Design of a new ignition system for the Ariane third stage was approved by the European Space Agency (ESA) and Arianespace, the commercial operator of Ariane, at the end of November.

The design, proposed by SEP (Society Europeenne de Propulsion) following studies since last summer, is now being extensively tested.

Modifications to the engine involved:

- Triplication of ignition power.
- Better distribution of energy in the combustion chamber by two jets deviated by 45 degrees with respect to the longitudinal axis.
- Re-timing of the ignition moment.

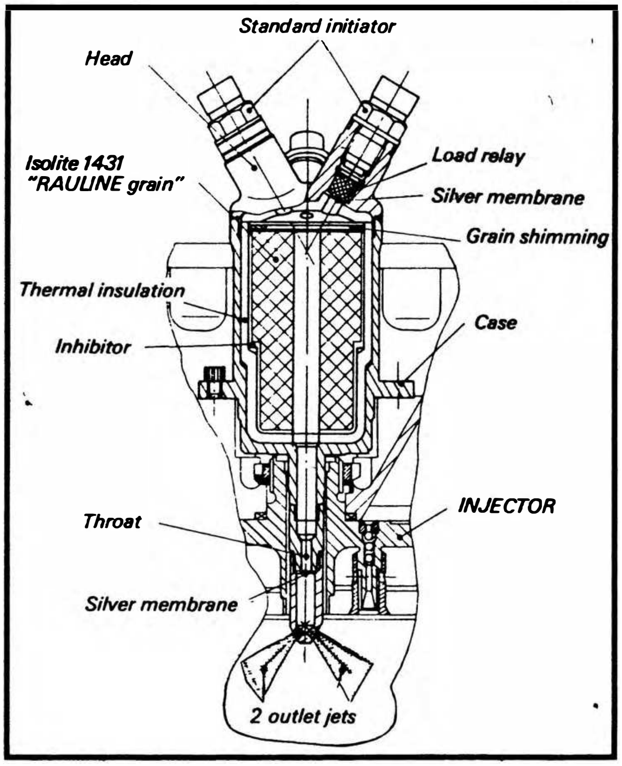
The more powerful igniter differs from the previous version in the following specifications:

- New Isolite loading with improved performance; gas temperature is higher, mass output is almost trippled, and total propellant mass is about 50 per cent greater.
- Gas is not admitted into the chamber through one central channel running parallel to propellant flows as previously, but through two symmetrical jets secant to the flows at a 45 degree angle.
- Igniter start is delayed 200 milliseconds.
- Opening of the generator's hydrogen injection valve is set forward by 50 milliseconds.

The V18 Board of Inquiry, which presented its findings at the end of November, considered that the new system allowed pressure to rise more regularly, reduced ignition delay and lessened sensitivity to temperature variations.

An announcement of the launch date for the next Ariane could be made later this month or in early March. The launch manifest (see ***Spaceflight***, November 1986, p.375) is also being up-dated.

The igniter configuration chosen for the resumption of flights.



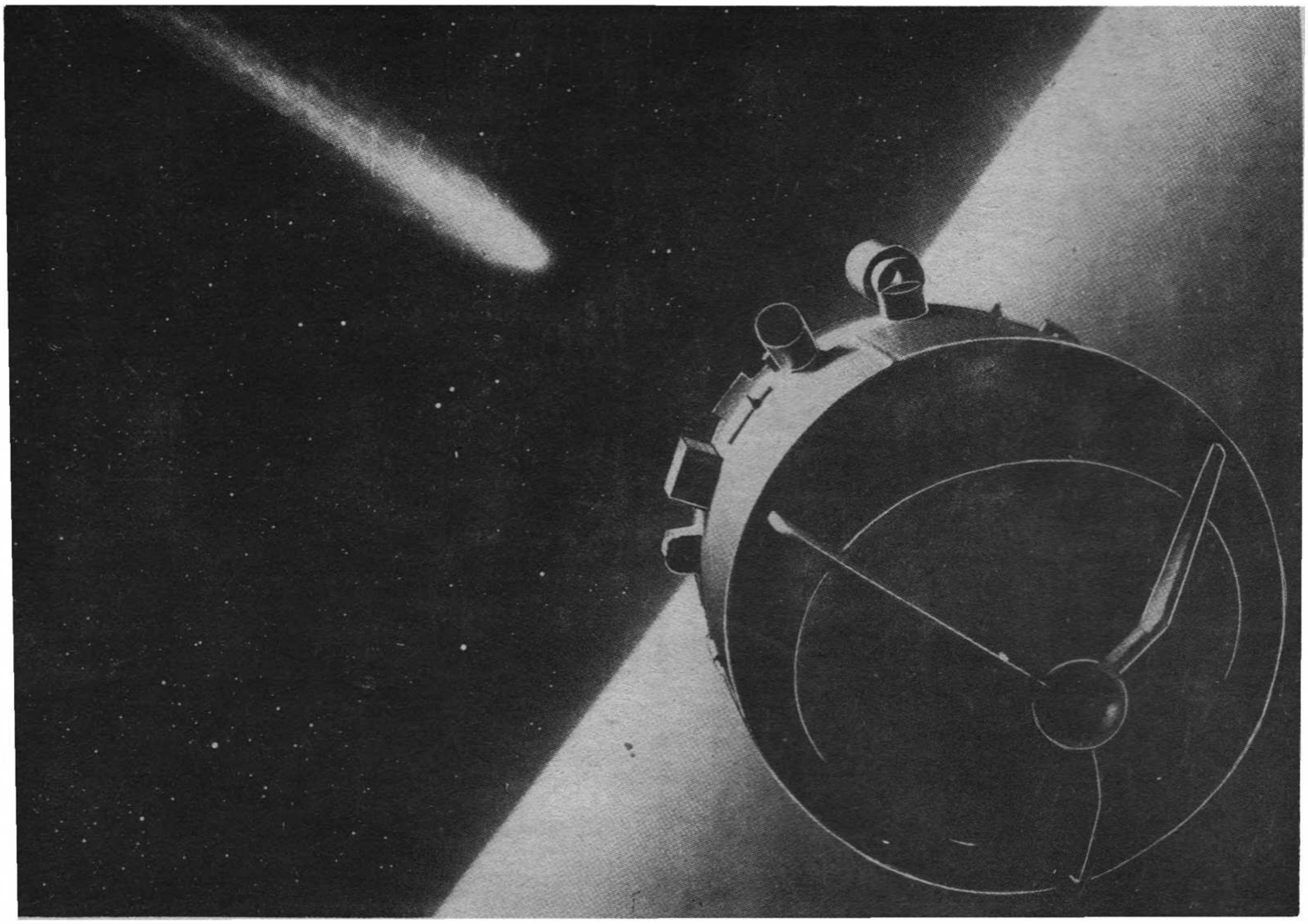
ITALY TO USE ARIANE

Arianespace is to launch the first Italian telecommunications satellite following the signing of a contract early last month (January).

ITALSAT will be placed into geostationary transfer orbit on a dual launch in mid-1990 by an Ariane 4, the upgraded version of the European expendable launch vehicle. The launch will take place from the Guiana Space Centre in Kourou (French Guiana).

The satellite has been built by the Italian manufacturer Selenia Spazio as prime contractor. It is a pre-operational advanced telecommunications satellite that will test digital voice channels in the new 20-30 GHz frequency band. Six transponders will offer an 11,000 telephone circuits capacity and three others will ensure data transmissions.

EUROPEAN RENDEZVOUS



Artistic representation of ESA's Giotto and its encounter in March of last year with Comet Halley. The spacecraft could be used to fly-by a second comet in 1992.
© *Julian Baum*

GIOTTO AWAITS NEW ORDERS

Scientists are examining the possibility of using the now dormant Giotto spacecraft for a radio science experiment with the Sun when it approaches superior conjunction (far side of Sun in direct line with Earth) at the end of this year and in early 1988.

Using the spacecraft's S- and X-band dual radio links measurement of the physical parameters of the corona at various solar longitudes could be performed.

However, feasibility of the experiment, which would be funded as an ESA optional programme, has yet to be proved due to the unknown status of on-board systems.

Another possible assignment for Giotto – an encounter in 1992 with Comet Grigg Skjellerup – depends on the status of the on-board camera.

This could be checked during 1988 and if satisfactory the possibility of a second comet encounter would be considered as an option alongside other ESA science projects at the end of next year.

The encounter with Comet Grigg Skjellerup (a short period comet of 5.1 years) would involve Giotto in a swing-by manoeuvre close to the Earth in 1990. The spacecraft's successful close approach to Comet Halley (***Spaceflight***, April 1986 p.168, and May 1986 p.227) took place on March 13, 1986.

NATO CONTRACT FOR UK

British Aerospace Space and Communications division has won a contract worth more than £100 million to supply NATO with advanced military communications satellites.

This is the first time NATO has placed an order for satellites to maintain its front-line spaceborne communications system with a non-American contractor.

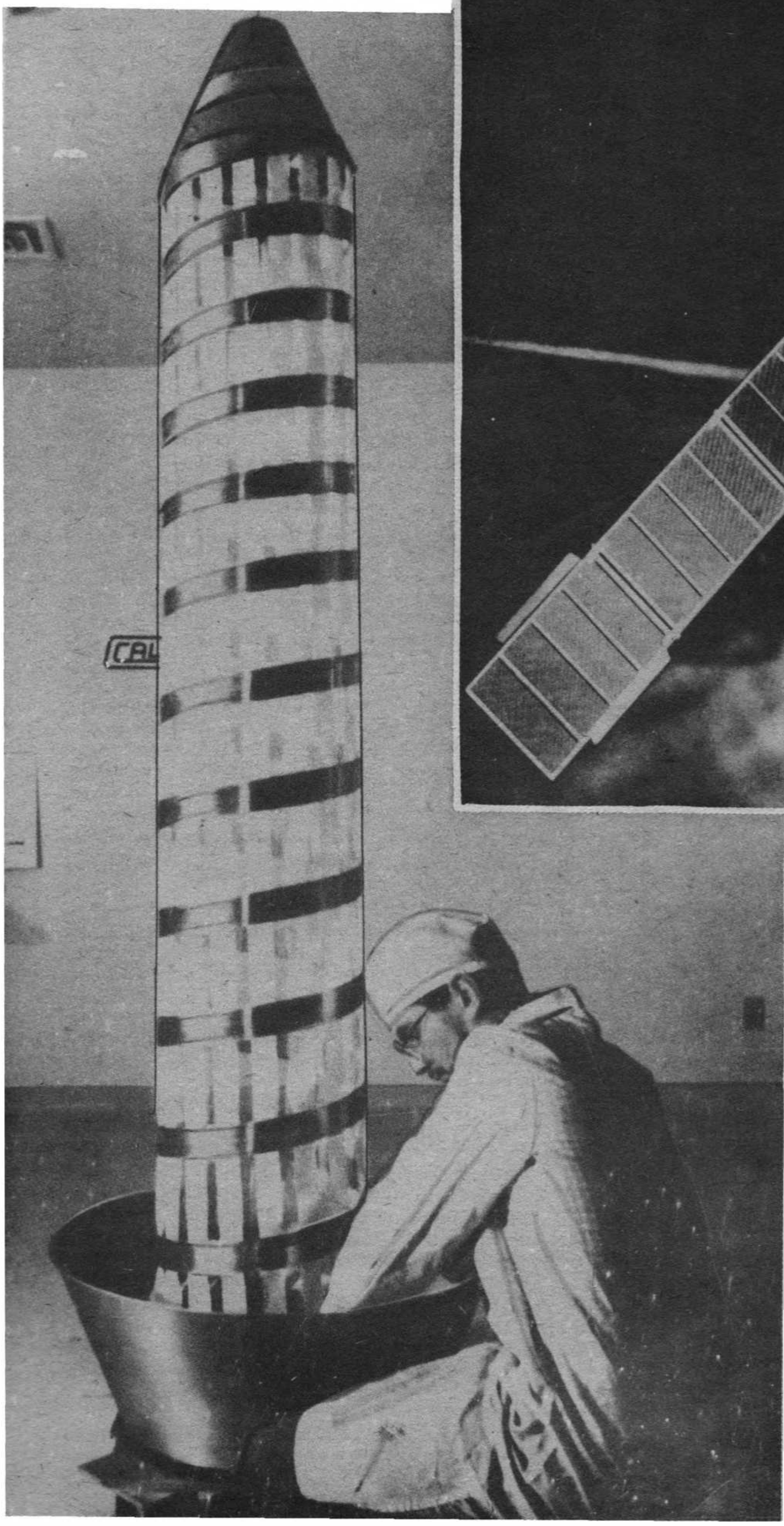
The BAe Space and Communications division at Stevenage, Herts, will be prime contractor for the complete satellite system and Marconi Space Systems, as principal sub-contractor, is to supply the advanced communications payload.

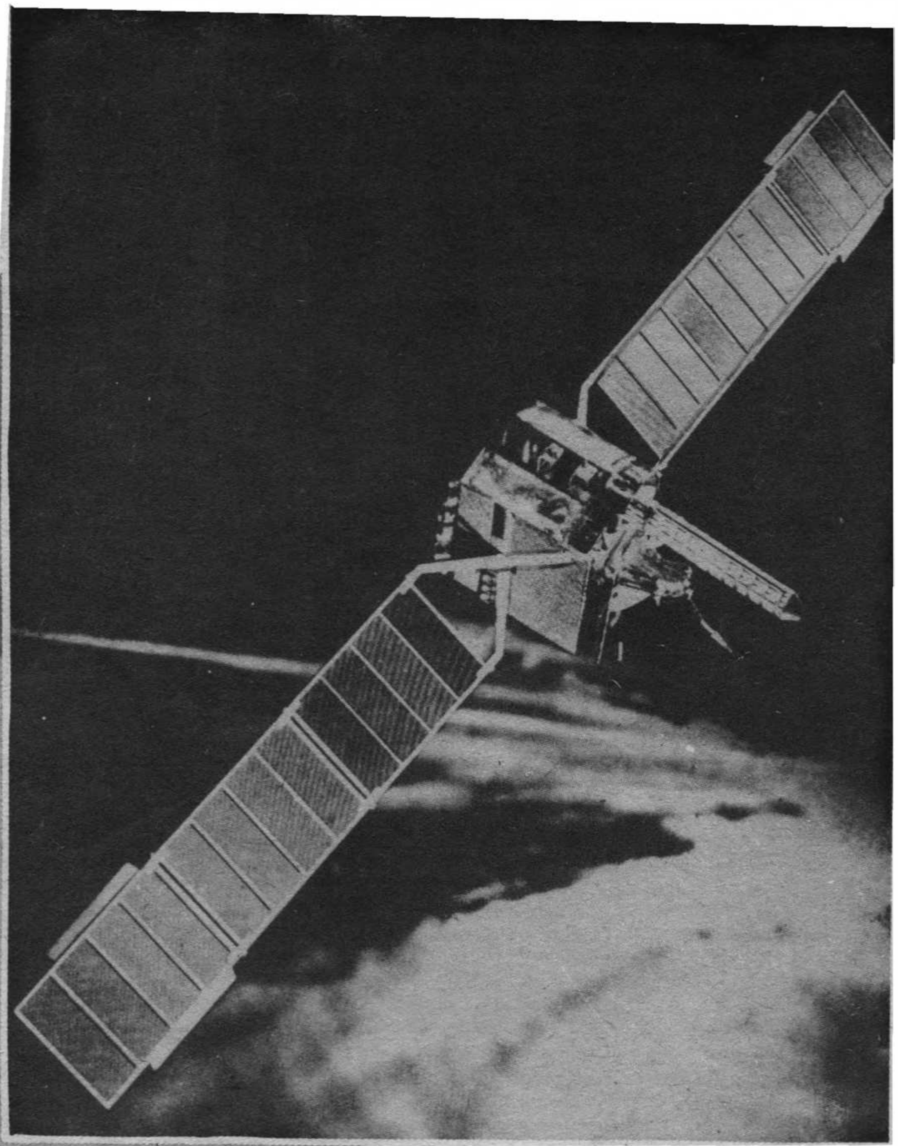
The satellites will be virtually identical to the United Kingdom's armed forces Skynet 4 (see opposite) series of communications satellites currently under construction by British Aerospace and for which Marconi supplies the communications package. Designated NATO IV, the first of the new satellites is to be launched in the early 1990s.

The choice by NATO of the British designed satellites has been influenced by the advanced performance of Skynet 4 and the cost effective solution it provides for NATO's communications requirements through to the turn of the century.

The contract is for two satellites and extends the order book of Skynet 4 type satellites to five.

SKYNET 4





The UK military communications satellite, Skynet 4, which was originally scheduled for a June 1986 Space Shuttle launch, has been re-scheduled for a possible 1988 launch on the Ariane rocket.

A novel feature of its design is its helical transmit/receive antenna which is stowed in a flat spiral, like a watch spring, and held down by pressure applied through a composite material top cone. When deployed it reaches 2.4 m (8 ft) in length. The antenna will provide Earth coverage from geostationary orbit over two narrow frequency bands with a radiation cone of 9.1 degree semi-angle. This antenna, and similar designs of the same type, are a development of Canadian Astronautics Limited and are expected to have applications for many future satellites.

BOOK NOTICES

An Astronaut's Diary

J.A. Hoffman. Caliban Press, 114 Westview Road, Montclair, N.J. 07043, USA. 1985. 50 pp. Booklet and Cassette. $13.

During his first flight in April 1985 aboard the Space Shuttle Discovery, Mission Specialist J.A. Hoffman kept a personal diary on a small cassette tape recorder. The original function of hand-held cassette recorders on the Shuttle was to give crew members an opportunity to make notes on experiments, operations and to record medical symptons for subsequent de-briefing. The original six hours of Hoffman's tapes have been edited to delete the technical references but retain the original sequence and spontaneity in which they were recorded.

The tapes, therefore, are probably the next best thing to actually experiencing a Shuttle flight and, even in edited form, provide an experience well-worth sharing. Flight 51-D had a crew of seven and mission plans to launch two satellites. The second of these was Syncom which, although successfully launched, refused to function. It was theorised at the time that the problem lay with a switch on the side of the satellite. A plan was devised whereby Jeff Hoffman and Dave Griggs were to leave the Shuttle to attach makeshift devices to the Shuttle's fifty-foot robot arm. Discovery was then to rendezvous with the satellite while Rhea Seddon used the arm to flip the switch and make the satellite operational once more.

Even though this was in vain, the switch not being the problem after all, the knowledge gained enabled a sub sequent flight to repair Syncom and put to useful life in geosynchronous orbit.

The cassette thus provides a real-time account of all this activity. The accompanying booklet includes additional matter edited out of the cassette.

The Search for Extraterrestrial Intelligence

T.R. McDonough, John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, PO19 1UD. 1986, 244 pp, £16.50.

From the dawn of history humans have believed that there were beings in the sky. Throughout the Middle Ages and as late as the 19th Century, Mars was widely thought to be inhabited. Indeed, only recently, the Viking spacecraft was sent to the planet to search for life and, beyond this, a long-standing search, even if of a relatively small character, has been under way to detect anything in the nature of extraterrestrial radio signals.

With the subtitle "Listening for Life in the Cosmos" this book explores hoaxes and false alarms as well as the scientific endeavours to determine the possible scale and extent of extraterrestrial life, including suggested answers to the Fermi paradox which posed the question, "If ET life is prevalent, where is everybody?"

The fact that this is a popular presentation is underlined by the inclusion of several cartoons and the choice of titles for many chapter and section headings. The same characteristics appear in the text, which varies from an informative scholarly approach to references to "Star Trek", UFO's etc. Nonetheless, this is a pleasing book to read and particularly interesting for its references to the feuds and quarrels of those who have participated in the search for other intelligent life.

Automatic Control in Space 1985

J.P. Chretien. Pergamon Press, Headington Hill Hall, Oxford OW3 0BW. 1986, 312pp, $68.75.

This book, the Proceedings of the 10th IFAC Symposium held in Toulouse, France in June 1985, presents an authoritative overview of recent developments and techical advances in the applications of automated control to space technology. Topics covered include geostationary satellites, scientific satellites, flexible systems, low-Earth orbit satellites, orbit and trajectory control, component technology, platforms, rendezvous and docking (RVD) and manipulators.

It will undoubtedly prove of particular interest to those in space agencies, aerospace and telecommunications companies, space research establishments and to control and systems engineers, astrophysicists, and to aeronautical and electronic engineers generally.

A Supplement to the Tuckerman Tables

M.A. Houlden & F.R. Stephenson. The American Philosophical Society, 104 South Fifth Street, Philadelphia PA 19106, USA. 1983, 564pp, $35.

This work is intended to supplement the well-known planetary, lunar and solar tables produced by Bryant Tuckerman in 1962 and 1964 respectively which, in two remarkably compact volumes, detailed positions of the five bright planets and the Moon and Sun over the entire period between 601 BC and AD 1649 at five or ten day intervals.

It owes its origin to the discovery of significant errors in Tuckerman's tabular positions of Mars, which led to a systematic comparison between his positions for the Sun and the planets and those computed from an integrated ephemeric. Serious errors were found only in the case of the longitude of Mars but these could amount to as much as 0.7 degree, considerably more than the Moon's apparent diameter.

Quasar Astronomy

D.W. Weedman. Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1986, 217 pp, £25.

The discovery of quasars nearly a quarter of a century ago introduced a new dimension to astronomy. Not only did astronomers suffer the shock of learning that major sources of energy existed in the Universe unrelated to the nuclear fusion processes in stars, but also the revelation of new observational spectral windows opened up by radio astronomy, revealing extraordinary and totally unanticipated things.

The author, concentrating on observational astrophysics rather than theory, describes his conclusions on the nature of quasars, their distribution and their evolution in the Universe. He summarises not only what is currently known but indicates the research methods used and points to some of the still unanswered questions.

After reviewing the cosmological framework (with the necessary equations) the book discusses the observed properties of quasars and continues by summarising techniques for analysing quasar data obtained with various kinds of telescopes indicating, at the same time the potentialities of new instruments presently being developed. A major part of the book deals with the distribution of quasars in spacetime, a subject extensively discussed in current research literature.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Maps of the Heavens

G. S. Snyder. Andre Duetsch, 105-106 Great Russell Street, London WC1. 1984, £25.

This work chronicles the colourful pageantry of the history of celestial map making, supported by 75 illustrations, 50 of which are in full colour, together with a short text outlining salient points from each.

To the West, constellations were part of a system that persisted until the early 16th Century and appeared in the first printed maps of the stars by Durer. As the Copernican revolution took hold, the star catalogues of the ancients were cast aside as astronomers, with the aid of the telescope, started to rechart the heavens. Such data, used by Brahe, Kepler, Bayer and Flamsteed, provided the basis for further development which led the way for advancement in all branches of science in the 16th and 17th Centuries, with celestial maps reaching a zenith of achievement towards the end of that time.

By the 18th Century, many new constellations were appearing but the growth of modern astronomy brought celestial cartography to a close even though, in its time, it had produced maps of outstanding interest and beauty.

Even those who might be familiar with some of the well-known star atlases of former times will be intrigued by the wealth of illustrations in this volume. A wide selection reveals the variety of ways in which man has interpreted his vision of the sky, ranging from concentric rings of the spheres, surmounted by an omnipotent God, to the depiction of demons and spirits.

Solar Flare Prediction

C. Sawyer, J.W. Warwick, J.T. Dennett. Colorado Associated University Press, Box 480, University of Colorado, Boulder, Colorado 80309, USA. 1986. 179pp. $25.

The Sun is so important to us that any changes in its activity concern us all, particularly as the effects on Earth may be felt soon afterwards, e.g. as is the case with long-range radio communications which tend to 'fade' during periods of solar activity.

A major variation can stem from solar flares. These were quite unsuspected before 1859 but, nowadays, considerable effort goes into predicting the effects of flares on human activities. The result is that solar flare prediction represents a new field of solar activity though, until the origin of flares is fully understood, the possibility of reliable prediction remains remote.

Solar Flares result from a complex process which involves a sudden release of energy and radiation and an alteration of the magnetic field. The classical view of a solar flare, i.e. a sudden local brightening on the Sun, is only a part of this process and one of the few which can be seen in the narrow visible band of the spectrum. A big flare in the Sun's chromosphere is an enormous event which could cover a thousandth of the solar surface and stay bright for hours. On the other hand, microflares may be a hundred times smaller and last for only a few minutes. Even though, overall, a flare is only a minor fluctuation in the Sun's radiation, some, even from their remote location on the Sun, can seriously affect human activity.

Flares are of particular interest to astronauts orbiting near the Earth for a sudden brust of energy could reach them some hours later and pose a serious threat to both men and equipment.

The 11-year sunspot cycle imposes a wide variation in the frequency of flares but is only partially useful in attempting accurate forecasting. As this book shows, the current line of research is based on probability forecasts, which can then be compared to actual events on a daily basis. The problem is that forecasting relatively rare events, which may vary in activity with the sunspot cycle, needs a long period beforehand in which to accumulate a sufficient sample of forecasts and occurrences if any worthwhile results are to be achieved. Keeping detailed records is important so the propsal for a sun-synchronous satellite carrying continuously sunlit solar-radiation monitors is of particular interest.

The Extraterrestrial Life Debate

M.J. Crowe, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1986, 680pp, £40.

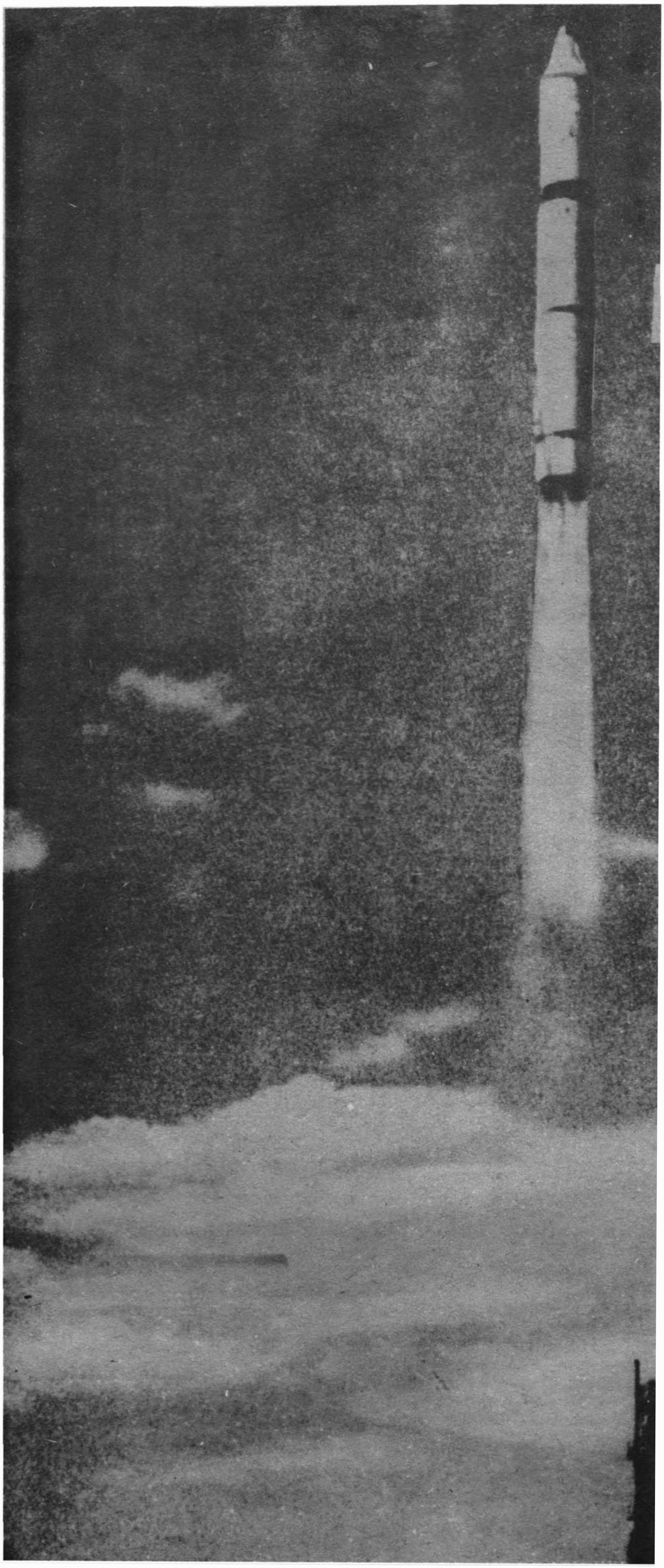
This is the first in-depth study in English of the international debate which took place between the period 1750-1900 on the question of whether intelligent extraterrestrial life existed or not, though this was actually an issue which began much earlier and has probably been discussed almost from the beginning of recorded history.

Using the history-of-ideas approach, the author describes the controversies revealing in the process how these inflenced astronomical, philosophical and religious thought to a far greater extent than had formerly been realised. The majority of leading astronomers over the last two centuries participated in the debate, their views interacting with developments in Newtonian mechanics, Darwin theory and the steady stream of discoveries in steller astronomy and astrophysics.

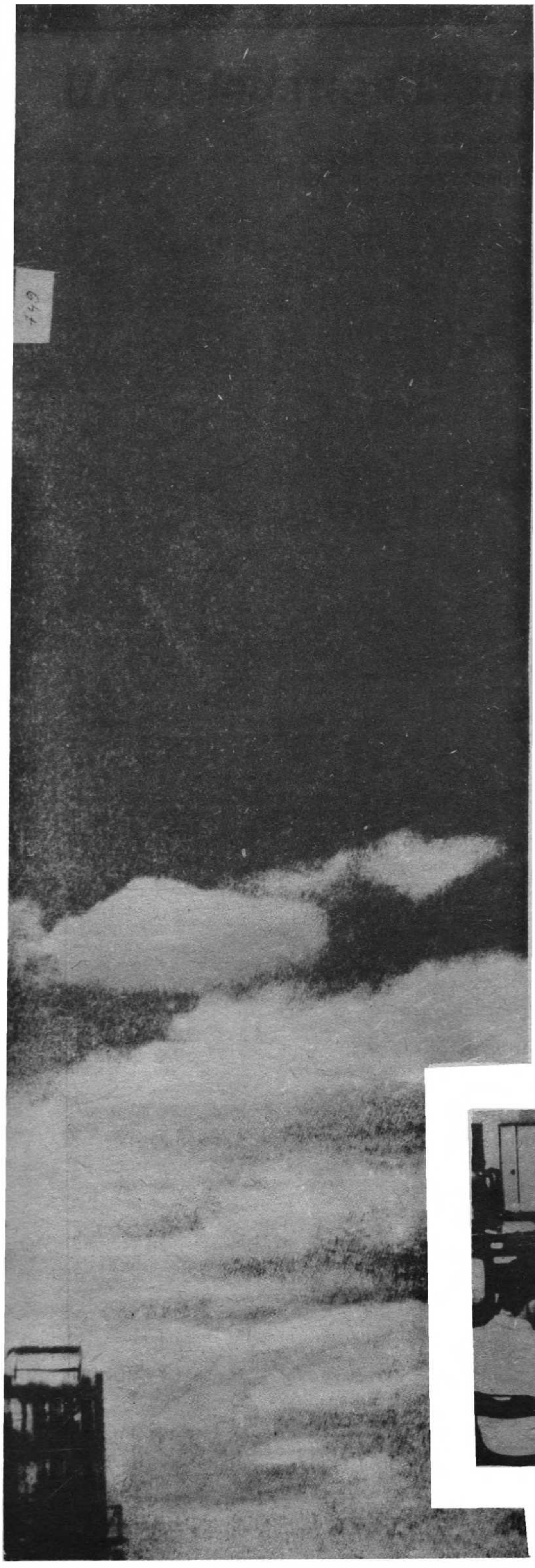
In the course of his study the author demonstrates the extent to which religious convictions have affected ideas of extraterrestrial life and how religious and theological claims have also been affected in turn.

Rather than merely claim that the discovery of extraterrestrials will have a profound future influence on human thought, the author shows how a long-standing and widespread belief in extraterrestrial life has, for centuries, already affected our attitudes.

CHINA



The launch of a CZ-2 vehicle from the original northern launch site of Shaung Cheng Xi. See map on p. 47.



In Business and Advancing Fast

Chinese Space Activity 1985-1986

by Phillip S. Clark

During 1985 and 1986, China's low-key space programme saw the launch of three satellites. Two of the payloads were recoverable observation satellites while the third was a geosynchronous orbit communications satellite. In addition, the Chinese continued to operate their first geosynchronous communications satellite, launched in 1984.

The Chinese have now released new information about their space programme, details of which are presented here together with a review of the development of Chinese space activities, particularly in 1985 and 1986.

China's space programme has recently reached commercial maturity and promises to become a major new force on the international space scene.

Introduction

The Chinese are credited with the invention of the solid propellant rocket and a Chinese citizen Wan Hu is said to have attempted a rocket powered flight. The true Chinese space programme started in 1956 when in the spring a 12-year development programme was instigated to integrate rocket and jet engine technology into important State plans. A space committee was set up by the Chinese Academy of Sciences in 1963 and two years later the first plans were made for a practical satellite [1].

Table 1 provides a summary of the satellite launch attempts during 1969 to 1984 [2,3], and it will be noted that with this paper a different system of satellite numbering is used.

Chinese Launch Sites

Two launch sites are used by the Chinese for satellite missions. The original site was known in the West at Shuang Ch'eng-tzu, but the Chinese refer to it as Jiuquan: this site is located at 41.2 deg N. 100 deg E.

Inside the Flight Control Centre where vehicle performances is being monitored by technical operations staff.

CHINA

In 1984 when China introduced its advanced CZ-3 booster, a new launch site was brought to operational status. The site is call Xi Chang and is located near 28 deg N. 102 deg E.[4].

Chinese Launch Vehicles

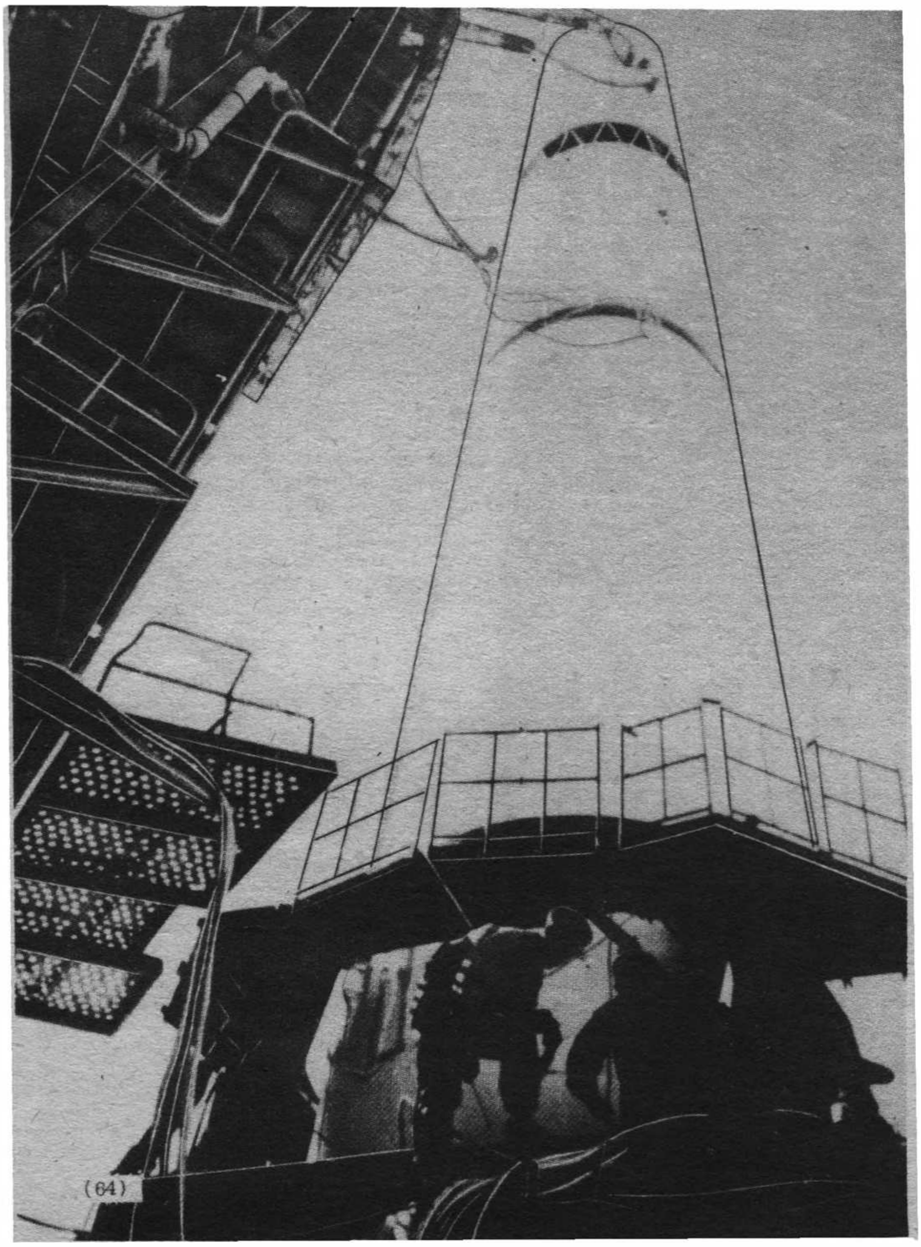
Four Chinese launch vehicles have been used operationally, although two vehicles are very closely related: these are detailed in Table 2. The original vehicle was the three stage CZ-1 ("Chang Zheng" – Long March) and this was used to orbit the first two successful satellites in 1970 and 1971, as well as a probable failed launch attempt in 1969.

The two closely-related launch vehicles are the FB-1 ("Feng Bao" – Storm) and the CZ-2. Originally these two boosters were not differentiated. The CZ-2 had better electronics than the FB-1 and its orbital capacity was also greater. The FB-1 was used to launch non-recoverable satellites during 1974-1981 while the CZ-2 began flights in 1974 and is still used exclusively to orbit recoverable satellites. CZ-1, CZ-2 and FB-1 have only been launched from the Jiuquan site.

The CZ-3 vehicle was specifically designed for geosynchronous orbit missions: this variant completed two missions in 1984 (one was a partial failure) and a single mission in 1986. This is a three stage booster, comprising the two stage CZ-2 booster with a new third liquid hydrogen/liquid oxygen stage added. Details of the CZ-3 booster are given in Table 3. CZ-3 has been flown only from Xi Chang.

Included in Table 2 is the CZ-1C booster which the Chinese claim to be available for commercial satellite launches. This variant, however, has not yet completed an orbital mission.

Working on the launch pad during launch vehicle assembly.



Continued Operations of Satellite STW F-2 (1984-035)

The first successful Chinese geosynchronous satellite was launched in April 1984 and after being allowed to drift it was placed on station over 125 deg E. This location had been registered as STW-1, STW-2 located over 70 deg E having been registered for a future mission.

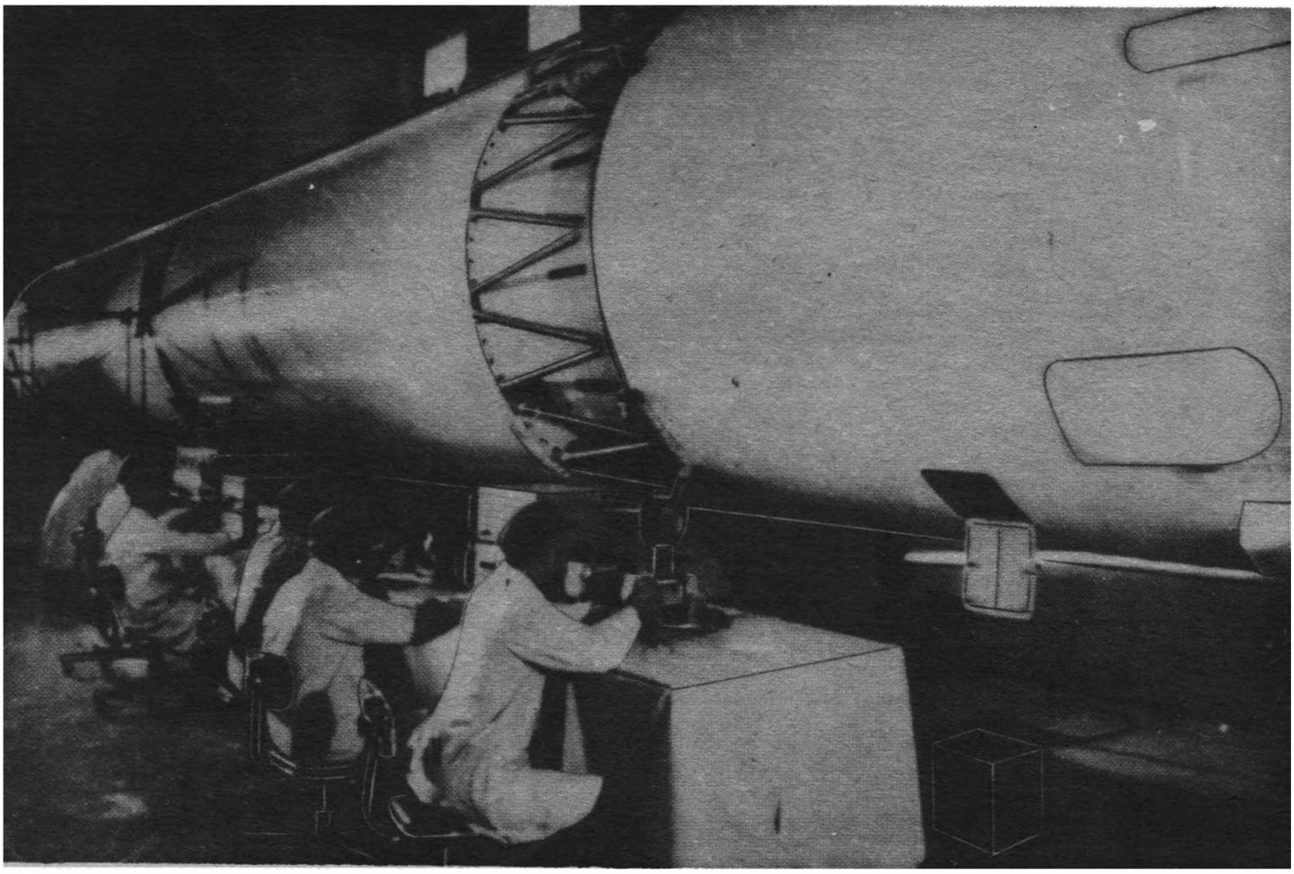
Because of irregularities in the Earth's gravitational field and perturbations due to the influence of the Moon and Sun the satellite does not remain stationary. The Chinese initially placed the satellite in an orbit with a period of less than 1436.07 minutes (the Earth's rotational period) and the orbit is perturbed so that the period increases. As the period increases towards 1436.07 minutes the satellite drifts in longitude towards the east but when the period continues increasing past 1436.07 minutes the satellite drifts back towards the west. After the satellite has returned to its original longitude (approximately) the Chinese controllers fire the satellite's thrusters and reduce the orbital period to begin a fresh cycle of drifting.

Table 4 provides a summary of the station-keeping manoeuvres, which are the subject of a separate study [5], and a monitoring of the cycles shows the satellite is still being used by the Chinese more than two years after its launch – despite the satellite being expected to have a far shorter operating time.

Earth Observation Mission, SKW-13 (1985-096)

The seventh successful Chinese recoverable satellite was launched from Jiuquan on October 21, 1985 and was recovered five days later on October 26 at about 03.50 GMT. An object (an instrumented adapter between the satellite proper and the booster's second stage ?) was left in orbit by the recoverable capsule and decayed on November 7, while the rocket body decayed four days earlier.

An official from the Chinese Ministry of Astronautics described the mission's success as an important step forward for China's space technology and said that it would aid the country's economy and modernisation programme and help develop international space co-operation. The satellite was used to survey land resources and the data it obtained were used in mineral exploitation, forestry development, vil-



Assembly and checkout of integrated stages of a CZ-3 launch vehicle in the modern vehicle checkout building at Xichang.

lage and town planning and environmental protection [6].

Some pictures have been released of Chinese satellite recoveries [7, 8] and these show that the craft is similar in shape to the beehive Soyuz descent craft, although on a smaller scale. The Royal Aircraft Establishment (RAE) estimates the radius of the descent craft to be 0.7 metres and its mass 1850 kg. The total craft has an estimated length of 1.55 metres and a diameter of 1.4 metres flaring to 2.25 metres [9].

Communications Satellite STW F-3 (1986-010)

The third CZ-3 booster was launched from Xi Chang on February 1, 1986 and after 3.5 revolutions in the eccentric geosynchronous transfer orbit the satellite was placed in a geosynchronous drift orbit on February 3 at 02.06 GMT [10]. Chinese statements suggested that this was the time that the satellite attained its geosynchronous location, but this is not true. After injection into the drift orbit over 146.3 deg E the satellite drifted west until about February 18: between February 18-20, the satellite's orbit was lowered and it was stationed over 103.5 deg E.

The location of the satellite was a surprise, in that its location was expected to be over 70 deg E, the STW-2 position. The satellite was basically the STW F-2 back-up payload with an improved 1.2 metre long, 0.7 metre wide graphite epoxy spot beam antenna which confined the satellite transmissions to the Chinese mainland.

Table. 1 List of Chinese satellite launch attempts, 1969-1984.

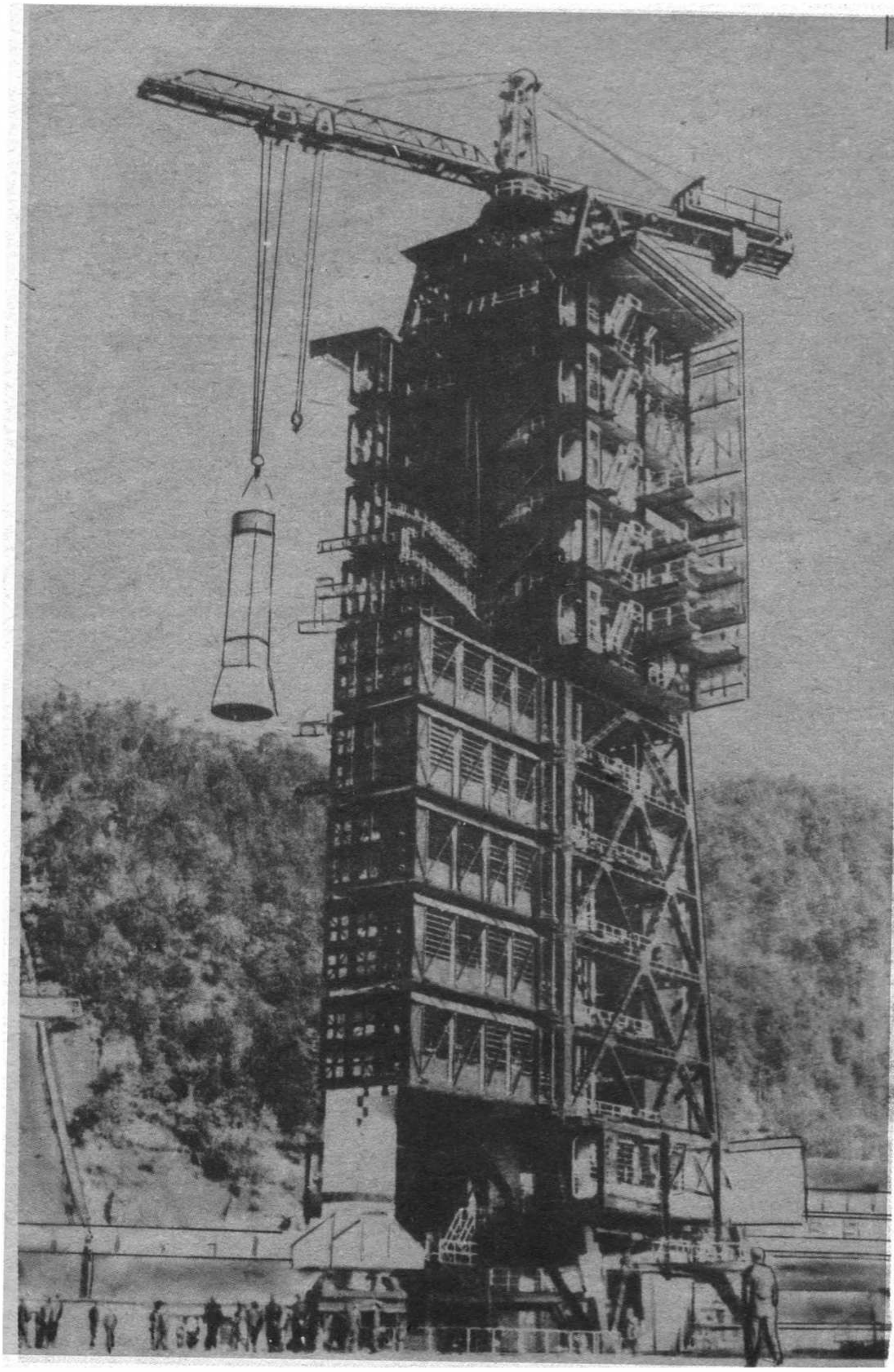
Launch Date	International Designation	Chinese Designation	Name	Booster
1969 Nov 1	(Failure)		SKW	CZ-1
1970 Apr 24	1970-034	Tungfanghung	SKW 1	CZ-1
1971 Mar 3	1971-018	Practice 1/SKW-2	SKW	CZ-1
1974 Jul 12	(Failure)		SKW	FB-1
1974 Nov 4	(Failure)		SKW	CZ-2
1975 Jul 26	1975-070		SKW 3	FB-1
1975 Nov 16	1975-111		SKW 4	CZ-2
1975 Dec 16	1975-119		SKW 5	FB-1
1976 Aug 30	1976-087		SKW 6	FB-1
1976 Dec 7	1976-117		SKW 7	CZ-2
1978 Jan 26	1978-011		SKW 8	CZ-2
1979 Jul 30	(Failure)		SKW	FB-1
1981 Sep 19	1981-093	SKW-9	SKW 9	FB-1
1982 Sep 9	1982-090		SKW 10	CZ-2
1983 Aug 19	1983-086		SKW 11	CZ-2
1984 Jan 29	1984-008		STW F-1	CZ-3
1984 Apr 8	1984-035	Tungfanghung 1/STW-1	STW F-2	CZ-3
1984 Sep 12	1984-098		SKW 12	CZ-2

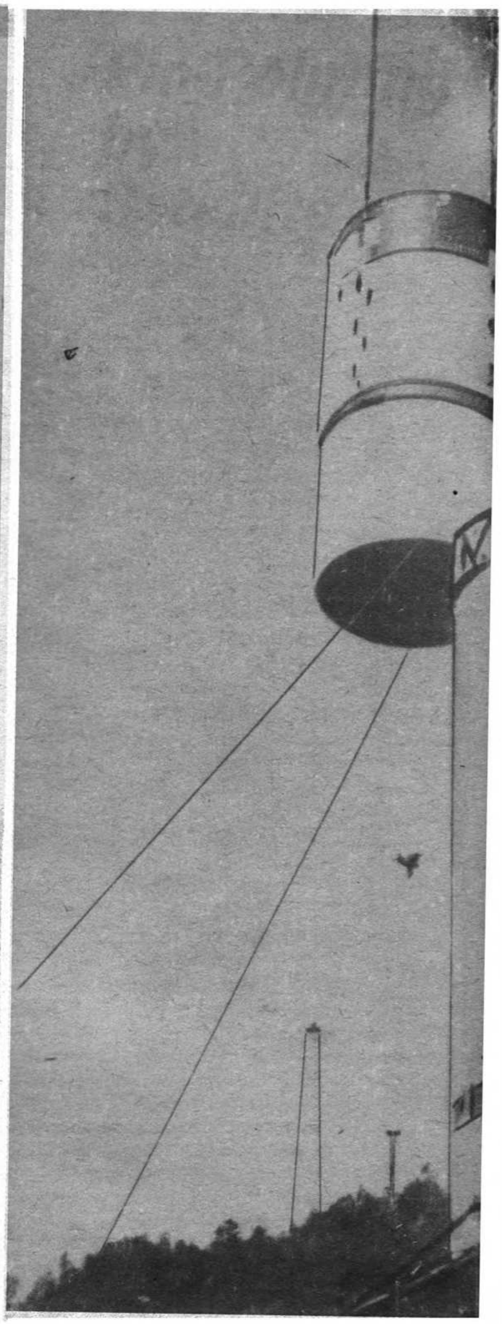
NOTES
This list includes both launches which reached orbit and those which are reported not to have reached orbit: of the various failure reports only those which are deemed most probable are listed. The failure of November 1974 is confirmed by the Chinese and that of July 1979 was announced by the Soviet Union. The names by which the Chinese have called their satellites are shown where such names are available. The satellite launched in 1971 has been called Practice 1 in one Chinese article and SKW-2 in another. The STW communications satellites are identified by flight (F) number. The SKW 9 launch placed three satellites in orbit. The name Tungfanghung was originally applied to the first successfully launched satellite, while the first geosynchronous satellite has sometimes been called Tungfanghung 1 by the Chinese. The satellite designations used in this paper differ from those used in references 2 and 3.

Table 2. Summary of Chinese Launch Vehicles.

Vehicle	Stages	Launch Mass	Payload Capacity	
CZ-1	3	81.6 tonnes	300 kg to 440 km circular,	70 deg
CZ-1C	3	88 tonnes	400 kg to 600 km circular,	70 deg
			400 kg to 400 km circular,	99 deg.
FB-1	2	191 tonnes	2500 kg to 200- 400 km,	63 deg.
			2000 kg to 200-2600 km,	63 deg.
CZ-2	2	193 tonnes	3000 kg to 200- 400 km,	63 deg.
CZ-3	3	202 tonnes	1400 kg to 200-35786 km,	31.1 deg.

NOTES
The CZ-1C uses the same lower two stages as the CZ-1, but is to have a liquid propellant third stage rather than a solid propellant stage. The FB-1 and CZ-2 boosters are closely related, but the FB-1 has a lower payload capacity and has now been retired. The CZ-2 will probably be used for retrograde (99 deg) orbit flights. The CZ-3 is configured for geosynchronous transfer orbit missions.





Assembly of a CZ-3 launch vehicle at the Xichang launch site. Centre: the second stage is mated with the first. Left: the third

Table 3. Details of the CZ-3 Booster.

	Stage 1	Stage 2	Stage 3
Engine Designation	YF-2 (4)	YF-2 (1)	YF-73 (1)
Thrust, tonnes	280	70	5
Specific Impulse, sec	264	264	425
Burn Time, sec	132	129	451+291
Stage drymass, tonnes	10	3.5	2.3
Propellant load, tonnes	140	34.2	8.7
Stage length, metres	20.22	7.51	7.48
Stagediameter, metres	3.35	3.35	2.25
Fuel	Nitrogen Tetroxide		L Hydrogen
Oxydiser	UDMH		L. Oxygen

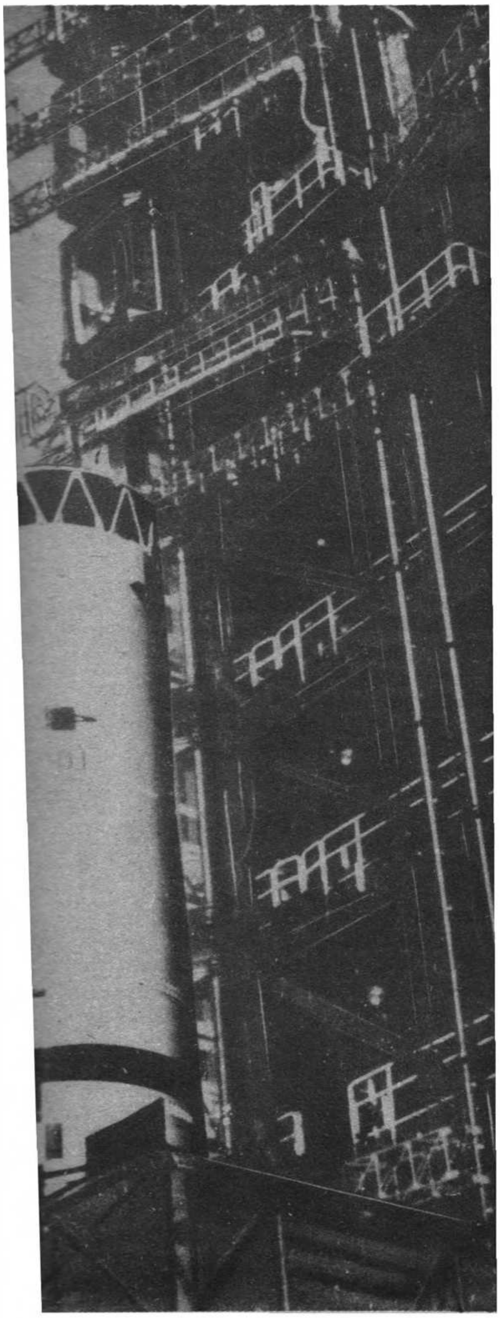
NOTES

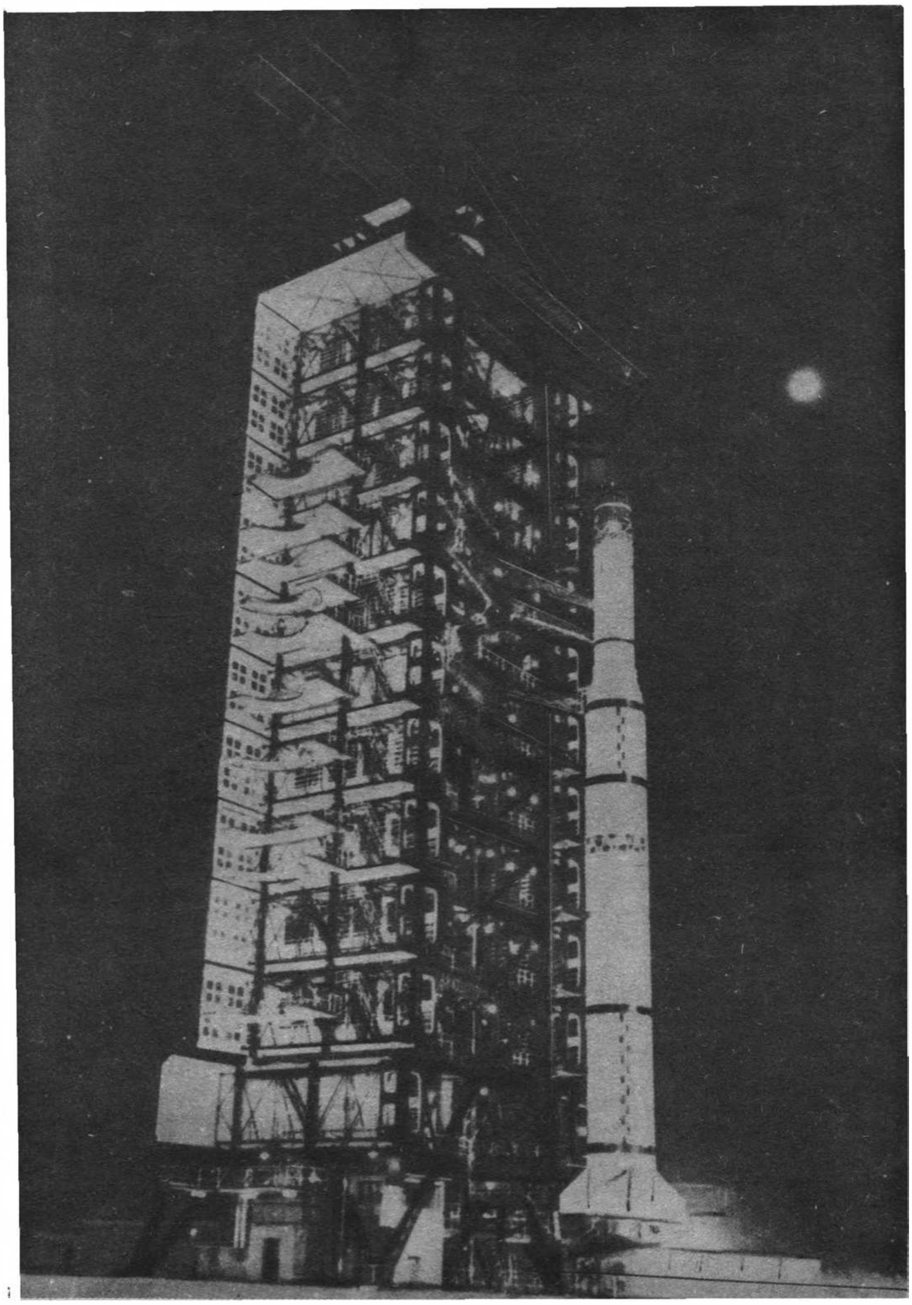
These details are either given in the Long March 3 User's Manual or derived from the data contained therein. The total length of the booster is 44.68 metres. The payload shroud is 7.27 metres long (including the adapter to the third stage) and has a maximum diameter of 3.0 metres. The numbers in parentheses are the number of engines used in that stage: the thrust values are those for the total stage rather than for the engine itself. The third stage is re-started in flight: and initial burn lasts for 451 seconds for the basic orbital injection and then after coasting for 197 seconds it re-ignites for the manoeuvre to geosynchronous transfer orbit.

Like the STW-2 satellite, the STW F-3 satellite has been subject to orbital drift caused by perturbations which are to be fully analysed along with the STW F-2 drift [5]. The manoeuvres are summarised in Table 6, using the same format as Table 4. STW F-3 was still operating at the end of 1986.

Recoverable Satellite SKW-14 (1986-076)

On October 6, 1986 a new recoverable satellite was launched by China, the orbiting of the satellite being announced by the Kettering Group within hours of the event (see *Spaceflight* December 1986). The Chinese did not announce the mission until the





stage is raised into position. Right: the payload is in position and the noze cone is being installed.

satellite was back on Earth. However, the announcement when it came was unusually full of detail.

The launch came at 05.40 GMT and the satellite was placed in an orbit with the announced parameters: inclination – 57 deg, period – 90 minutes, perigee – 180 km and apogee – 400 km. The satellite was recovered at 04.20 on October 11, the first time the Chinese announced an actual recovery time [11]. The mission announcement said that the information collected by the satellite can be used in a survey of terrestrial resources, prospecting for mineral resources, water conservancy, environmental protection and oceanographical and seismological research. As with the satellite launched in 1985, the People's Insurance Company of China provided the insurance service for the launch and recovery of the new satellite.

The instrumented adapter left in orbit at the time of capsule recovery decayed on October 23, two days after the second stage of the CZ-2C launch vehicle.

Future Space Flight Plans

China has announced plans for uprating its launch vehicles, and some details are available of future satellite programmes. Here, these details will be summarised, although it must be stressed that the time-scales presented may not be met.

Launch Vehicle Developments

It has already been noted that the CZ-1 is being marketed commercially with a new upper stage. The original CZ-1 used liquid propellant for the first two stages, while the third stage used solid propellant. The new variant is the CZ-1C which has a liquid propellant third stage. This variant has not yet made an orbital flight.

It would seem that the original CZ-2 has been up-rated already, since photographs of the most recent launches show the booster carrying the designation CZ-2C. In 1985 the Chinese indicated that they were considering the up-rating of the CZ-2 and the CZ-3 with the addition of solid propellant strap-on boosters to the first stage and the addition of a new solid propellant upper stage [12] (third stage for the CZ-2 ?).

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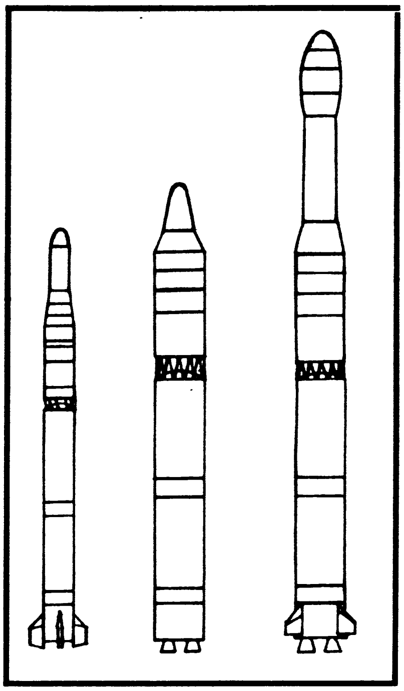


The family of Long March launch vehicles. Left: CZ-1. Centre: CZ-2. Right: CZ-3.

At the IAF Congress in 1986, details of more CZ-2 variants were announced [13], four in total. All the missions seem to be scaled for a launch from Xi Chang from where the CZ-2 can place 3.9 tonnes into a 28.5 deg, 200 km circular orbit. This vehicle with a stretched second stage could be used to carry a Hughes HS-376 communication satellite into a low parking orbit, with a PAM-D stage being carried for the manoeuvres to geosynchronous orbit.

The CZ-2 could also be used with a Hughes HS-399 communications satellite: in this version, the satellite with a mass of up to 1710 kg would be placed into a geosynchronous transfer orbit by the two stage CZ-2 and then its own apogee motor would perform the geosynchronous orbital injection.

A further CZ-2 variant could place a Molniya satellite into its drift orbit of about 400-40000 km, although the orbital inclination of the Soviet system (62.8 deg) probably could not be matched.

The most ambitious new CZ-2 variant would give the Chinese a major launch vehicle. A much stretched second stage would be carried, but the first stage would be augmented by either four or eight strap-on boosters. In the four strap-on booster version nine tonnes could be placed in orbit, while the eight strap-on version could orbit 13 tonnes. It is possible that this variant is the CZ-4 which the Chinese have recently mentioned.

Another source described the CZ-4 as being capable of placing 2040 kg into geosynchronous transfer orbit: this would use eight YF-2 engines clustered in the first stage (the existing first stage with four strap-ons, each having a single YF-2 ?) with the possible procurement of a new upper stage from the United States [14].

Using the CZ-4, a new geosynchronous payload launcher is being planned. Designated CZ-4L, this is described as an up-rated CZ-3 with four strap-ons [15]. The current third stage would be replaced by a new cyrogenic stage, and this combination would place 5.3 tonnes into geosynchronous transfer orbit, compared with 1.4 tonnes for the existing CZ-3. The first flight of the CZ-4L is planned for 1991.

Of the different CZ-2 derivatives described above, some are certain to

TABLE 4. Station-keeping manoeuvres of STW F-2 (1985-1986).

Pre-Manoeuvre Orbit				Post-Manoeuvre Orbit			
Epoch	Date	Perigee km	Apogee km	Epoch	Date	Perigee km	Apogee km
1985	Jan 20	35787	35796	1985	Jan 28	35777	35784
	Apr 2	35788	35794		Apr 12	35776	35789
	Jun 7	35787	35795		Jun 12	35774	35791
	Aug 22	35782	35803		Apr 23	35781	35784
	Oct 27	35783	35800		Nov 8	35776	35786
1986	Jan 11	35787	35797	1986	Jan 17	35781	35784
	Mar 11	35786	35796		[Apr 21]		
	May 18	35771	35814		Jun 7	35771	35799
	Jul 6	35777	35802		Jul 25	35777	35786
	Oct 18	35788	35800		Oct 23	35776	35788

NOTES
This Table is in the same format as Table 3 of reference 3. The orbits are based upon the Two-Line Orbital Elements and often after a manoeuvre it can take time before the Elements reflect the correct orbit: this accounts for the omission of potential data from this Table. There was a break in the inclusion of Two-Lines between March 11 and April 21 1986, during which period there was a manoeuvre.

TABLE 5. Chinese satellite launches during 1985-1986.

Launch Date	Time GMT	Satellite	Incl deg	Period min	Perigee km	Apogee km
1985 Oct 21	05.04	SKW 13	62.97	90.16	171	393
1986 Feb 1	12.36*	STW F-3	31.07	631.01	438	35546
			0.14	1450.09	35895	36225
			0.11	1440.41	35787	35955
			0.11	1436.99	35779	35790
1986 Oct 6	05.40*	SKW 14	56.97	90.09	173	385

NOTES
The launch times marked * are those announced by the Chinese: the one for SKW 13 is estimated. SKW 13 and SKW 14 were launched by the CZ-2 booster (CZ-2C variant) and STW F-3 was launched by the CZ-3 booster. Orbital data are derived from the Two-Line Orbital Elements. The first set of data for STW F-3 relates to the rocket body, the remaining sets relating to the initial positioning of the satellite over 103.5 degrees E. This satellite has sometimes been called Tungfanghung 2 by the Chinese.

TABLE 6. Station-keeping manoeuvres of STW F-3 (1986).

Pre-Manoeuvre Orbit				Post-Manoeuvre Orbit			
Epoch	Date	Perigee km	Apogee km	Epoch	Date	Perigee km	Apogee km
1986	Mar 28	35785	35794	1986	Apr 1	35778	35790
	May 8	35788	35790		May 11	35784	35785
	Jun 17	35774	35804		Jul 4	35780	35793
	Jul 12	35783	35793		Jul 27	35781	35788
	Aug 29	35786	35792		Aug 30	35782	35784
	Oct 26	35788	35793		Oct 28	35778	35789
	Dec 1	35784	35791		Dec 4	35785	35788

NOTES
The format of this Table is identical with Table 4.

remain paper studies only. The version designated CZ-4 above is almost certain to fly, since the CZ-4L is derived from it.

Planning further into the future, the Chinese have begun the early definition studies of a new booster in the same class of the American Saturn-1, and this is expected to fly in the mid-1990s [12].

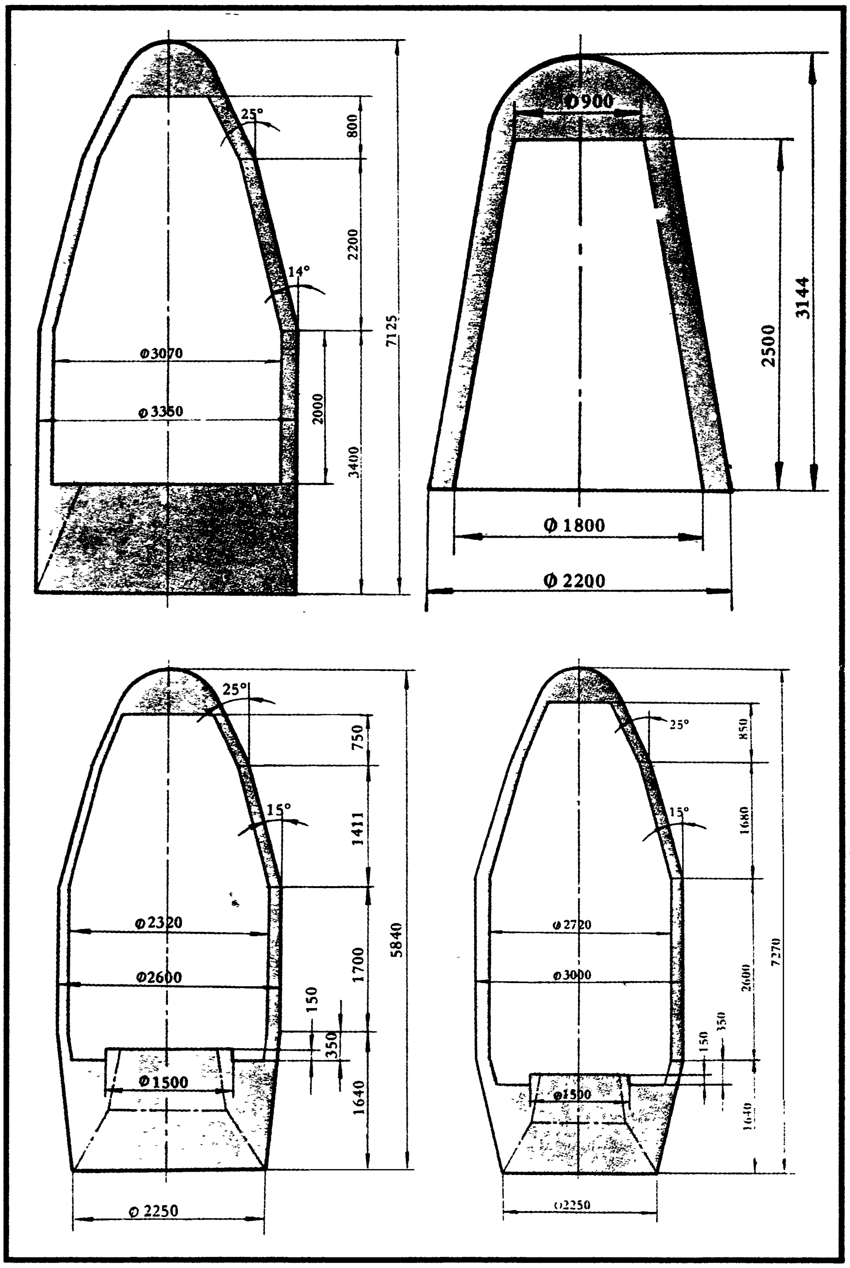
Multiple Payload Options

Again, at the 1986 IAF Congress the Chinese discussed studies which were being undertaken for the orbiting of multiple small satellites [16]. The CZ-2 was to be the basic booster and the Chinese expected four satellites could be launched into low Earth orbit. A typical configuration would be an upper satellite with a mass of 300-1000 kg and a diameter of two metres or less. Below this satellite would be a three tier container with smaller satellites. These would have masses of 50-300 kg and would be launched in "frisbee" fashion, like the Syncom satellites from the American Shuttle: the maximum diameter for these smaller satellites would be 1.6 metres.

For such missions the Chinese suggest launches into orbit from the Jiuquan site. The perigee range is 175-300 km, with apogees of 800-1000 km. Two orbital inclinations are suggested: 63.4 degress for geophysical missions or 98.9 degrees. The satellites could carry small propulsion systems to manoeuvre from the orbits used by the Chinese boosters.

New Observation Satellite

Although not fully detailed, the Chinese are planning the launch of a new image transmission satellite which will supplement the existing recoverable satellites. The new satellite is planned for a launch in 1988-1990 and its specifications are said to be similar to those of the French SPOT Earth resources satellite launched in 1986.



Usable volume of available nose cones. Upper diagrams: CZ-2 nose cones. Lower diagrams: CZ-3 nose cones.

Communications Satellites

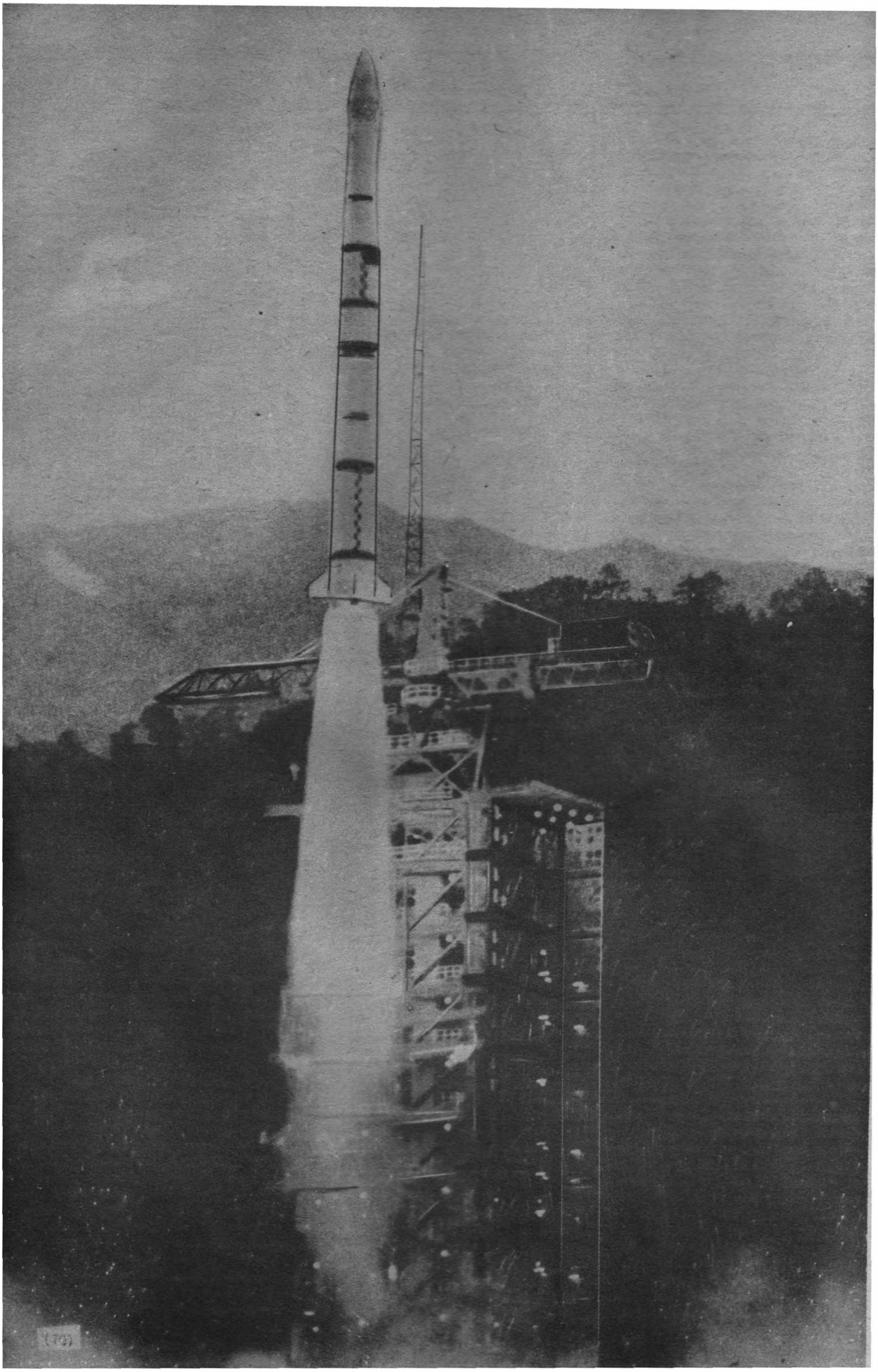
The registered STW-2 location has not yet been used, but presumably a future communications satellite will be launched there. There are plans to launch a "Block 2" communications satellite possibly in 1987. This will have a spot beam antennae and will be able to transmit microwaves. The Chinese said in 1985 that they hoped to have a direct broadcast satellite – designed by either MBB or RAC – launched in 1987 on either Ariane or the Shuttle, but the status of these plans is uncertain.

Meteorological Satellites

China is planning three different meteorological satellites. Later this year a prototype satellite is scheduled to be launched into an 809 km, 99 degree orbit, the payload having a mass of 700 kg. The Chinese have experienced difficulties in developing their own recorders and gyro systems for the satellite so plan to use American equipment for the mission [17]. The satellite, 1.4 metres square with two sets of three solar panels, will carry two radiometers and three channels for imaging in the visible and infra-red spectra. The digital data stream should have a resolution of 1 km. The Chinese hope that the satellite will operate for about a year.

The satellite will be launched with its orbital plane 60 degrees away from an American NOAA satellite. Nitrogen gas is being carried for attitude control which will be maintained using data obtained from reaction wheels, gyros and infra-red horizon sensors.

China is also planning advanced meteorological satellite missions to both polar orbit and to geosynchronous orbit: the latter can be expected in the early 1990s. From the data discussed in terms of the multiple satellite studies, it would seem that the polar orbit missions will be launched from Jiuquan using a CZ-2 booster, while the geosynchronous launches should come from Xi Chang using the CZ-3 booster.



CHINA

A Manned Space Programme – Again?

In the 1970s there were reports that the Chinese were planning a man-in-space programme, and photographs were released apparently showing men training for space missions. Later, the Chinese said that manned missions had been scrapped because of a lack of funding.

At the beginning of September 1986 the Chinese indicated that their plans for a manned space mission were again being put into practice: the complete statement is reproduced below [18]:–

> China has made a simulated cabin for space shuttles and the selection of its first group of astronauts is underway, according to [yesterday's] overseas edition of People's Daily.
>
> Chinese manned space flights could be a reality in the near future, thanks to major breakthrough both in theory and key technologies, the authorities disclosed.
>
> A life support system involving control of the cabin's air including composition, temperature, pressure and purification, has been completed. Also, technical problems in providing food, drink and clothing for astronauts have been worked out.
>
> A centre for research on space flight has been completed with a series of experiments. It will be the training ground for astronauts.
>
> Foreign experts visiting the centre said China's space technology is in line with international developments both in terms of research and equipment. The centre is one of the few advanced ones in the world, the visitors said.

Clearly, the Chinese launch vehicles currently being operated are insufficient for manned space operations, but the CZ-4 vehicle with either four or eight strap-ons could be used as a basis for a manned launch vehicle. The Chinese have usually expressed an interest in orbital laboratory work, and one can therefore speculate that the Saturn-1 class booster, work on which is at a preliminary stage, could perhaps orbit a Salyut-class laboratory, while the CZ-4 could launch a small manned ferry with the laboratory's crew. It may be too much to expect the Chinese manned space programme to begin with a reuseable vehicle, despite their use of the word "shuttle" in their announcement.

Commercial Considerations

For some years the Chinese have been offering some of their launch vehicles to potential commercial users, but it was only following the loss of Challenger on the Shuttle mission 51L in January 1986 and then Ariane V18 in May 1986 that Chinese offers began to be looked at anew. Prior to these losses, some customers had examined

Left: A CZ-3 launch vehicle clears the gantry at the Xichang launch site *Below:* The recovery team inspect a spacecraft capsule on its return to Earth.

TABLE 7. Long-lived Chinese objects in orbit.

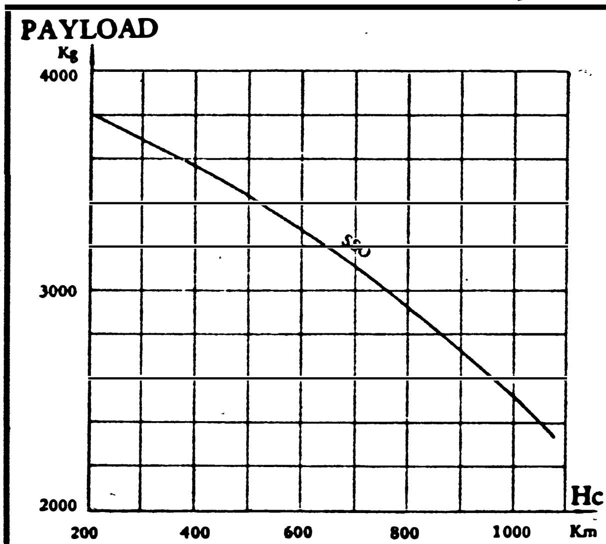
Mission	Object	Orbital Epoch	Incl deg	Period min	Perigee km	Apogee km
SKW 1	1970-034A	1985 Jan 11.55	68.44	112.68	436	2264
		1986 Jan 9.12	68.44	112.66	436	2262
		1986 Dec 5.17	68.43	112.65	437	2260
	1970-034B	1985 Jan 7.48	68.39	107.08	425	1758
		1986 Jan 4.36	68.40	106.98	424	1750
		1986 Dec 13.43	68.40	106.89	423	1741
STWF-1	1984-008A	1985 Jan 1.89	36.15	163.36	459	6583
		1986 Jan 4.74	36.18	163.38	469	6575
		1986 Dec 16.12	36.19	163.38	476	6567
STWF-2	1984-035A	1985 Jan 1.57	1.09	1436.20	35784	35793
		1986 Jan 8.57	1.97	1436.35	35782	35801
		1986 Dec 10.64	1.31	1436.24	35780	35798
	1984-035B	1985 Jan 1.26	30.66	629.98	488	35442
		1986 Jan 2.26	30.52	629.77	413	35506
		1986 Dec 13.45	31.11	629.73	460	35458
STWF-3	1986-010A	1986 Dec 10.49	0.13	1436.13	35786	35789
	1986-010B	1986 Dec 11.84	30.58	630.96	561	35420

NOTES
This Table lists all of the Chinese objects which were in orbit at the end of 1986. The data are derived from the Two-Line Orbital Elements.

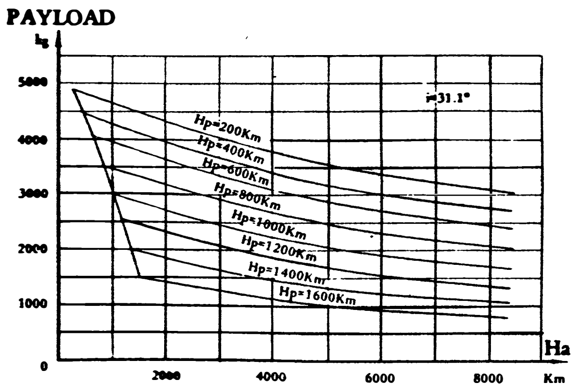
the Chinese system but final orders had not been forthcoming.

The Chinese claim the potential to build about 12 CZ-3 boosters each year but at present vehicles are built only as required: there are no stocks of boosters awaiting launch. Using the Xi Chang launch site, the Chinese expect that a realistic launch rate is currently six to seven missions per year with 35 days being required between launches. This launch rate will increase when construction of a second CZ-3 launch pad at Xi Chang is finished. The User's Manual for the CZ-3 booster says that launches are best undertaken from Xi Chang during the dry season each year, November – April [19].

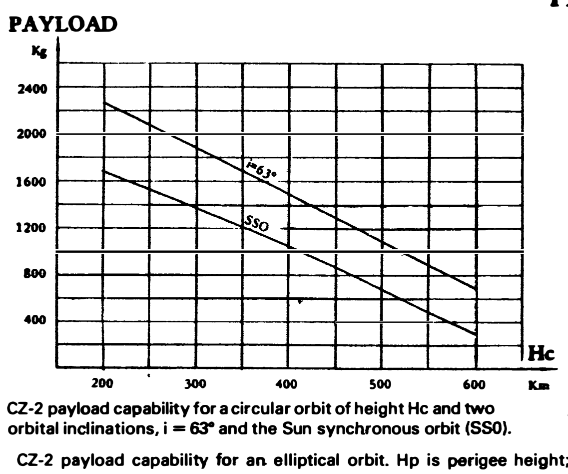
Using the CZ-3 booster, the Chinese expect to attain a geosynchronous transfer orbit with the following



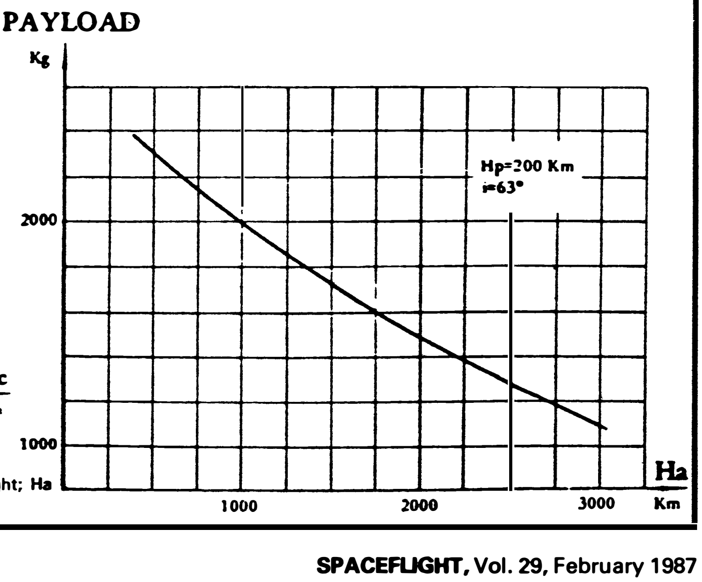
CZ-3 payload capability for a Sun synchronous circular orbit of height Hc.



CZ-3 payload capability for an elliptical orbit. Hp is perigee hieght; Ha is apogee height and i is orbital inclination.



CZ-2 payload capability for a circular orbit of height Hc and two orbital inclinations, i = 63° and the Sun synchronous orbit (SSO).



CZ-2 payload capability for an elliptical orbit. Hp is perigee height; Ha is apogee height and i is orbital inclination.

parameters [20]: Perigee 200 km; Apogee 35786 km; Inclination 31.1 deg; Argument of perigee 179.2 deg.

The errors in the launch vehicle performance are expected to result in the following standard deviations in the orbit [21]: Semi-major axis 50 km; Perigee 6 km; Inclination 0.07 deg; Argument of perigee 0.29 deg; Longitude of ascending node 0.14 deg.

If required, the commercial user of the launch vehicle can arrange for variations in the inclination and the argument of perigee. At present the CZ-3 can place 1.4 tonnes into the above transfer orbit, and the satellite must then perform the circularisation manoeuvre at an appropriate time.

The Chinese have set up Great Wall Industries for the commercial launch vehicle programme, and the vehicles currently on offer are the CZ-1C, the CZ-2 and the CZ-3. The CZ-1C, as already noted, has yet to make an orbital flight. The Chinese have met with most success in the marketing of the CZ-3 booster. The following reservations have been announced for the booster:–

Dominion Video Satellite Inc: two direct broadcast satellites. The first is to be launched before December 1987 and the second before March 1988

Western Union: Westar 6-S to be launched before March 1988.

Pan Am Pacific Satellite Corp: Pacific Star 1 to be launched before May 1988.

The Pacific Star 1 satellite is the renamed Westar 6 which was launched on Shuttle mission 41B and after the PAM stage failed to operate properly was recovered on mission 51A. The second satellite which failed after deployment on 41B and was recovered on 51A, Palapa B-2, is also being considered for a Chinese launch. Additionally, the Chinese have a letter of intent for the launch for an Iranian communications satellite, although the manufacturer of the satellite is unclear as of the time of writing. Discussions are taking place with Brazil for the possible launch of Brazilian satellites.

A single reservation has been made for the CZ-2 booster. A Swedish Mailstar satellite is scheduled for launch with a Chinese observation satellite: Mailstar will be carried underneath the Chinese satellite and will be propelled to its own orbit using a specially developed orbital transfer stage.

Concluding Comments

The Chinese space programme began very slowly but it has now reached a maturity which allows foreign satellites to be considered for launch. The launch rate of domestic satellites is not expected to exceed 3-4 each year (more probably 1-2 at present), although as more applications satellites are brought into the Chinese programme and the first flights in preparation for manned space activity take place, the launch rate will have to increase.

The projects for improved launch vehicles will give the Chinese the opportunity to become a major force in space, especially if the manned space laboratories are launched in the next decade or so.

A recovered satellite is winched aboard a helicopter for its return to base.

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In addition to the above sources, the author wishes to acknowledge the Goddard Space Flight Centre for the continued issues of Two-Line Orbital Elements and the Satellite Situation Reports, without which the numerical data presented here could not have been prepared.

SPACE AT JPL

The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

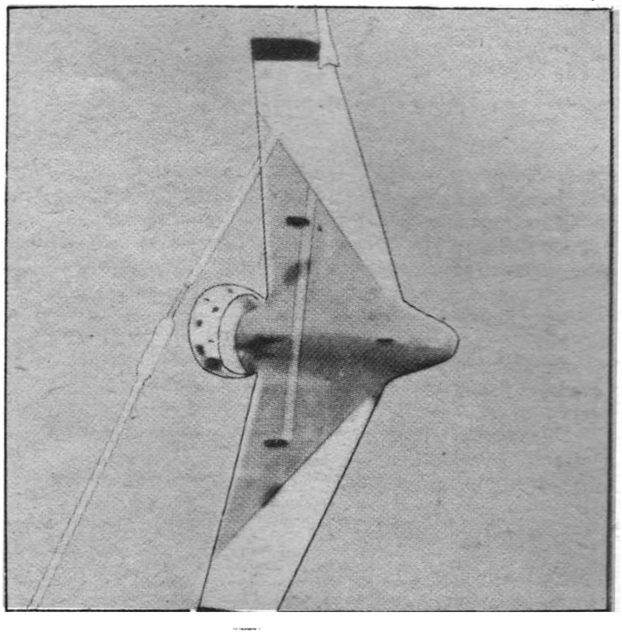
Sampling Venus

One of the highest priorities in the NASA report "An Augmented Program" (see the November 1986 edition of this column) is the return to Earth of planetary and cometary samples. Recently, in this vein, an imaginative mission concept for returning surface and atmospheric samples of Venus has been developed. Although the mission scenario calls for an intricate weaving together of several modes of transportation – with parachutes, balloons, aircraft and classical spacecraft – each mode has been tested, i.e., no new technology is required.

The value of sample returns rests, of course, on the opportunity to subject the returned material to prolonged and sophisticated examination in Earth-based laboratories. Samples have been returned from the Moon by US and Soviet missions, and considerable planning has been expended on obtaining material from Mars and from comets, but these objects "are a piece of cake compared to Venus," according to Kerry Nock of JPL. The relatively deep gravity well of Venus – the planet has about the same size and mass as the Earth – and its formidable atmosphere pose problems for the collection and return of samples.

Nock, Ross Jones of JPL (the study leader) and Dr. Jacques Blamont of the Centre National D'Etudes Spatiales in Paris (Blamont is currently a JPL Distinguished Visiting Scientist and originated the mission concept) have put together a scenario for a Venus Sample Return (VSR) mission. The motivation for their mission design is to avoid the use of complex, massive systems on the hostile surface of Venus. The basic concept is to parachute small samplers to the Venusian surface and, when their sampling is complete, lift them from the surface with balloons whence the samples are transferred to a small, robot airplane. The airplane delivers its cargo to an ascent rocket, hanging in the atmosphere under a balloon, and, finally, the ascent rocket rendezvous with a Venusian orbiter which carries the sample to Earth. Each of the six VSR mission phases will be examined in turn.

In this photograph, a prototype of the remotely piloted Aquila vehicle is seen capturing a tether (suspended from a balloon) on its wing hook. A system similar to this might link a sample-bearing balloon to an airplane in the atmosphere of Venus as part of a scenario to return samples from the second planet.
Lockheed



Phase one comprises the trip from Earth to Venus. The VSR flight system is assembled at the Space Station and injected into a 140-day trajectory to Venus. The 20,000 kg spacecraft is placed into orbit about Venus by means of aerocapture, although orbital insertion with a conventional propulsive manoeuvre would also be feasible. At this time, the VSR spacecraft is composed of four major elements: (1) the Venus Orbiting Vehicle (VOV), (2) Venus Descent Module 1 (VDM1) which contains the sampler packages, (3) Venus Descent Module 2 (VDM2) which contains the hot "air" balloon, two airplanes (one is a backup), and the ascent rocket, and (4) the Earth Return Vehicle.

Phase two commences with the separation of a descent module (VDM1) from the VOV followed by a deorbit burn of VDM1. As it approaches the surface, VDM1 releases three sampler packages that descend to the surface by parachute. More than one sampler is released in order to provide redundancy for that key activity; the sampling technique is planned to be a simple "grab" of about 1 kg of atmospheric and surface material. Each sampler is equipped with an ascent balloon which acquires buoyancy through the vapourisation of ammonia during the period, about one hour, that the sampler is on the surface. The design of the balloons is such that they will achieve a terminal altitude of between 50 and 60 km in the Venusian atmosphere. During the four-hour ascent to this altitude, the wind drift of the balloons is estimated to be about 500 km from their sample sites.

Phase three shifts back to the VOV from which the second descent vehicle (VDM2) begins its downward motion. The payload of the VDM2 is contained within an aeroshell. This package is guided toward the region of the atmosphere where the sample balloons have risen. The estimation of the balloons' locations is done by means of a radar onboard the VOV.

In Phase four, the airplane must autonomously locate the sampler balloons, using radar, recover the samples and return to the hot air balloon. These tasks must be done within a specified period of time because the airplane has a limited flying time and the hot air balloon will only stay aloft during daylight, while it is being heated. The latter lifetime is estimated to be somewhat greater than 50 hours. Since the delivery accuracy of VDM2, carrying the airplane, to the balloon region will be good to within ± 55 km, the roundtrip of the recovery airplane should not require more than 110 km of traverse, assuming that the balloons have not become much separated from one another and that the radar estimate of their positions is accurate.

Phase 5 involves the return of the samples to orbit with the aid of the three-stage ascent rocket hung below the hot air balloon, the airplane having first been caught in a net carried by the hot air balloon.

After rendezvous with the VOV, Phase six consists of the flight back to Earth. The samples are placed in a canister which describes a highly elliptical orbit about Earth and is retrieved by an orbital manoeuvring vehicle.

Although the mission concept is complex, all of the systems that are new to planetary missions are supported by terrestrial equivalents and could be tested on Earth.

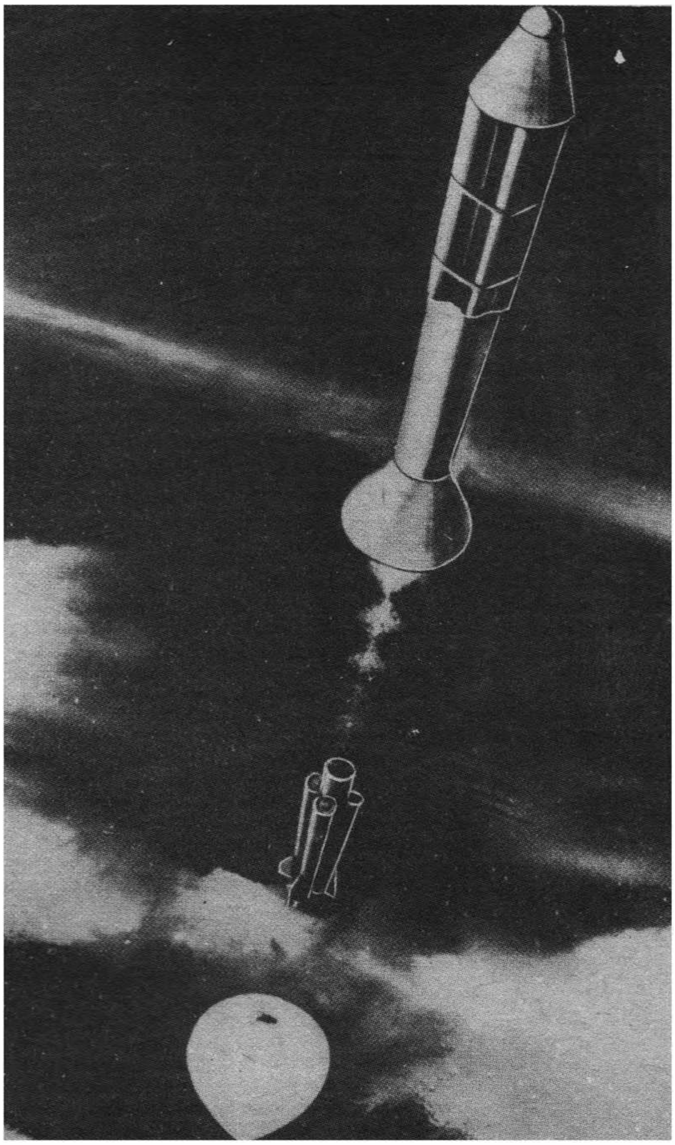
Descent systems for Venus *have* been employed: by the Soviet Venera missions.

The airplane would be based upon technologies already demonstrated by Lockheed's 118 kg Aquila air vehicle. A small prototype of this unmanned vehicle has engaged a tether hung aloft by a balloon in the Earth's atmosphere and the Aquila itself has been captured in a 5.4 m x 7.0 m net, the recovery being totally autonomous and guided by infrared sensors. The engine for the Venus airplane could not be airbreathing; it would utilise hydrazine and has been demonstrated in NASA's high-altitude, teleoperated Mini-Sniffer aircraft.

The point of launching the ascent vehicle from mid-atmosphere rather than from the surface of Venus is to circumvent the deleterious aspects of high atmospheric density which induces drag and heating and makes for inefficient engine performance (rocket engines like to expand from high density in the chamber to low density outside).

Surprisingly, the idea of launching a rocket suspended from a balloon goes back more than 50 years. In the musty pages of the July 1934 issue of *Modern Mechanix and Inventions* we read: "A balloon rocket conceived by a Wyoming inventor is expected to roar 43 miles into the stratosphere. Carried 11 miles by the balloon, the operator cuts loose, ignites two opposed rockets and soars 32 miles higher." The actual capability to launch a balloon-suspended rocket was demonstrated 30 years ago in Project Far Side (Ford Motor Company, Aeroneutronic Systems).

In addition to its intrinsic scientific merit, VSR would seem to be a good candidate for international cooperation: French balloons, Soviet landers, and US ascent and orbiting vehicles.



An artist's conception of the Far Side rocket shortly after its second stage engine has ignited. The US Air Force project, initiated in November 1956, featured a rocket suspended from a balloon and could serve as a prototype for part of the process of returning samples from the planet Venus.
Aeroneutronic Systems, Inc.

SETI And The Mind

The search for extraterrestrial intelligence (SETI) is a topic that is rapidly growing beyond its origin as a sidelight to radio astronomy and may emerge as one of the thematic forces of our time. The theory of evolution, formulated in the last century, and our century's rediscovery of the discrete aspects of the world, most visibly represented by digital computers and the theory of quantum mechanics, profoundly colour the way we think. This colouration extends well beyond the original domains of application in biology, computation and atomic physics, respectively. Similarly, SETI has a two-pronged thrust: the search *per se* and the philosophical and cultural spinoffs from this effort. Of course, a positive result – first contact – would prove to be an epochal discovery, but the effects of SETI are already being felt.

These effects are, to a significant extent, based upon the empirical datum of SETI that is apparent to all of us except, perhaps, UFO enthusiasts; extraterrestrials are absent from Earth. The importance of this datum was pointed out by Michael Hart in a 1975 article in the *Quarterly Journal of the Royal Astronomical Society:* if extraterrestrials exist, why have they not visited us? Where are they? Numerous attempts to explain this datum have appeared, and your correspondent's contribution, the epistemological solution, was discussed in the May 1986 edition of this column. Epistemology is the theory of knowledge. The epistemological solution submits that we do not observe extraterrestials on Earth because the rate of evolution for a technical species exceeds its rate for (potential) interstellar migration; a species setting out on a wave of colonisation would evolve into an advanced state, beyond our perception as we are to an ant's, long before reaching Earth. The virtue of the epistemological solution is that it avoids special pleading, such as explanations that claim we are alone in the galaxy or are in some kind of a quarantine zone.

But, to appreciate the larger issues at stake in the analysis of the Hart datum, it helps first to review some events in the history of ideas.

The view of the world that claims that matter is primary and mind is just a function dependent on matter has been, since ancient times, contrasted with the view

that mind is primary and matter is unreal or unimportant. In post-Renaissance times, if one were keeping score, it would seem that the idealistic philosphers – the proponents of mind – were initially winning the argument with their mort materialistic brethren. The works of Leibniz (1646-1716) (who was also a great mathematician and, with Newton, was a co-inventor of the calculus), Berkeley (1685-1753), Kant (1724-1804), Hegel (1770-1831), and Royce (1855-1916) presented an imposing case for the primacy of the mind.

However, the familiar outcome of winning the battle but losing the war saw idealism on the wane in the late 19th Century. The reason for this decline was that the main battleground changed; philosophers had been replaced by scientists in the centre ring of the intellectual arena, and the philosophy of science was dominated by the hard mechanism of Newton and Laplace. The momentum of this triumph has carried the materialistic view through the present day, but, ironically, the seeds of a new idealism were sown by the science of quantum mechanics, around the turn of the century, at the crest of the materialistic wave.

What is the connection of all this with SETI and Hart's datum? The epistemological content of the extraterrestrial problem of Hart puts it in a small but growing class of scientific problems that appear to rest upon idealistic foundations: the tight coupling of observer and observed in quantum theory, the so-called anthropic principles in cosmology, and Martin Harwit's prediction of the completion of astronomical discoveries in a few hundred years (see my paper in the December 1985 issue of *Vistas in Astronomy* for a review of these topics).

Thus, in working out some of the implications of SETI theory, we are participating in an activity that could redirect the flow of human thought in a manner every bit as decisive as the consequences of a successful search: first contact with extraterrestrials.

It is worthwhile to reflect upon just how far the dissolution of matter has gone and what the consequences are for the "other" SETI, the search *per se*.

The physicist Heinz R. Pagels has characterised the current view of matter: "the essential material reality is a set of fields" and "the intensity of a field at a point gives the probability for finding its associated quanta – the fundamental particles that are observed by experimentalists" (*The Cosmic Code*, Penguin Books, 1984). Not much interpretation is required to realise that the old idea of a material world, external to and independent of us, is in trouble. We "experimentalists" are woven into the field description and "particles of matter" depend partly upon our actions.

The change of importance with respect to SETI has not been the decline of materialism but rather the decline of its intellectual companion, naive realism: the idea of a common world to be viewed by ant, horse, human, and extraterrestrial. Therein lies the true difficulty facing SETI attempts – imagination that must be supplied to communicate between species which are wrapped up in their own subjective worlds. Although the epistemological solution, if accepted, solves the problem posed by Hart's datum, it identiries new challenges that a search strategy must overcome. But nobody said the search would be easy. Let's get on with it!

Comet Mission Progress

In October of last year NASA announced the selection of the scientific investigations which are now candidates for inclusion in the payload of the Comet Rendezvous Asteroid Flyby (CRAF) mission. The selection involved 14 instruments: three facility instruments developed by NASA and 11 developed by Principal Investigators and their teams. In addition, four scientists were selected to carry out interdisciplinary studies using data from several different instruments. A two-year instrument accommodation study will determine the final payload composition.

Following this selection, the first meeting of the Project Science Group of CRAF was held November 18-20 in Pasadena, California. The meeting, chaired by Project Scientist Marcia Neugebauer, introduced the newly selected investigations and investigators and served as a forum for discussing the mission, spacecraft, and other topics of scientific relevance.

The Imaging Science Subsystem, a facility instrument, will be used for the purpose of optical navigation as well as major comet and asteroid studies. The nine-person imaging team is led by Joseph Veverka of Cornell University.,

The second facility instrument, the Visual-Infrared Mapping Spectrometer (VIMS), will be used to investigate the mineralogy of the surface of the asteroid and the nucleus of the comet. It will also assist in the determination of the composition of surface ices and coma gases during the comet-rendezvous phase of the mission. A wide variety of cometary constituents are expected to be detected by VIMS: silicates, hydrocarbons, carbonates, sulfates, phosphates, clays, salts; ices including those of water, carbon dioxide, ammonia, methane, and hydrogen sulfides; plus molecules in the coma and ions in the tails. The team leader for VIMS is Thomas B. McCord of the University of Hawaii.

The spacecraft telecommunications subsystem (TCS) will, like the imaging subsystem, serve the needs of both science and engineering. Using it as a scientific (facility) instrument, the TCS team, led by Donald K. Yeomans of JPL, will conduct radio science investigations (see the June 1986 edition of this column) including estimation of the mass of the comet.

An important instrumentation package is the Penetrator (the Principal Investigator is William V. Boynton of the University of Arizona). The Penetrator is a pointed, spear-like projectile which will be fired from the spacecraft to imbed itself in the comet's nucleus to a depth of up to one metre. The Penetrator carries five instruments: a gamma-ray spectrometer, an accelerometer, thermometers, a calorimeter, and a gas chromatograph.

The Thermal Infrared Radiometer (Francisco P.J. Valero of NASA's Ames Research Center) will produce temperature maps of the surface of the nucleus. The maps will identify hot spots which may signify jetting activity.

A Dust Counter (W. Merle Alexander of Baylor University) will measure the mass of particles striking the spacecraft and will function as a warning device to protect the spacecraft against an excessive flux of particles from the nucleus. The Dust Particle Analyzer (Jochen Kissel of the Max Planck Institut für

Kernphysiks, Federal Republic of Germany) utilises a high-resolution mass spectrometer to determine the chemical composition of individual dust grains. The dust will also be examined in detail by means of a Scanning Electron Microscope and Particle Analyzer (Arden L. Albee of the California Institute of Technology). The images produced by this instrument will be compared with images of "cosmic dust" found high in the Earth's atmosphere in order to determine whether the Earthly detritus is of cometary origin. Gases liberated from heated samples of dust and ice will be subjected to analysis by the gas chromatography technique employed in the Ice and Dust Bulk Analyzer (Glenn C. Carle of NASA's Ames Research Center).

Three instruments will focus on the interaction between the comet and the solar wind: Magnetometer (Bruce T. Tsurutani of JPL), Plasma Analyzer (James L. Burch of Southwest Research Institute), and Plasma Wave Analyzer (Jack D. Scudder of NASA's Goddard Space Flight Center).

The composition and flow direction of gas and charged particles streaming from the nucleus into the surrounding coma will be studied by use of the Neutral Mass Spectrometer (Hasso B. Niemann of NASA's Goddard Space Flight Center) and the Ion Mass Spectrometer (Thomas E. Moore of NASA's Marshall Space Flight Center).

The CRAF project hopes to receive a Fiscal Year 1989 new start. A "new start" signifies presidential, then congressional, approval to move from the pre-project phase to the status of approved project, leading to launch. Fiscal year 1989 begins in October of 1988, and the President's budget for that year will be presented to Congress in January of 1988.

The baseline plan for CRAF, a mission to Comet Tempel 2, begins with a February 1993 launch using a Titan IV/Centaur G-prime launch vehicle. An alternative launch with a Shuttle/IUS combination in June 1993 is possible. This mission, unlike the baseline, would require a solar-electric propulsion stage in order to achieve Comet Tempel 2.

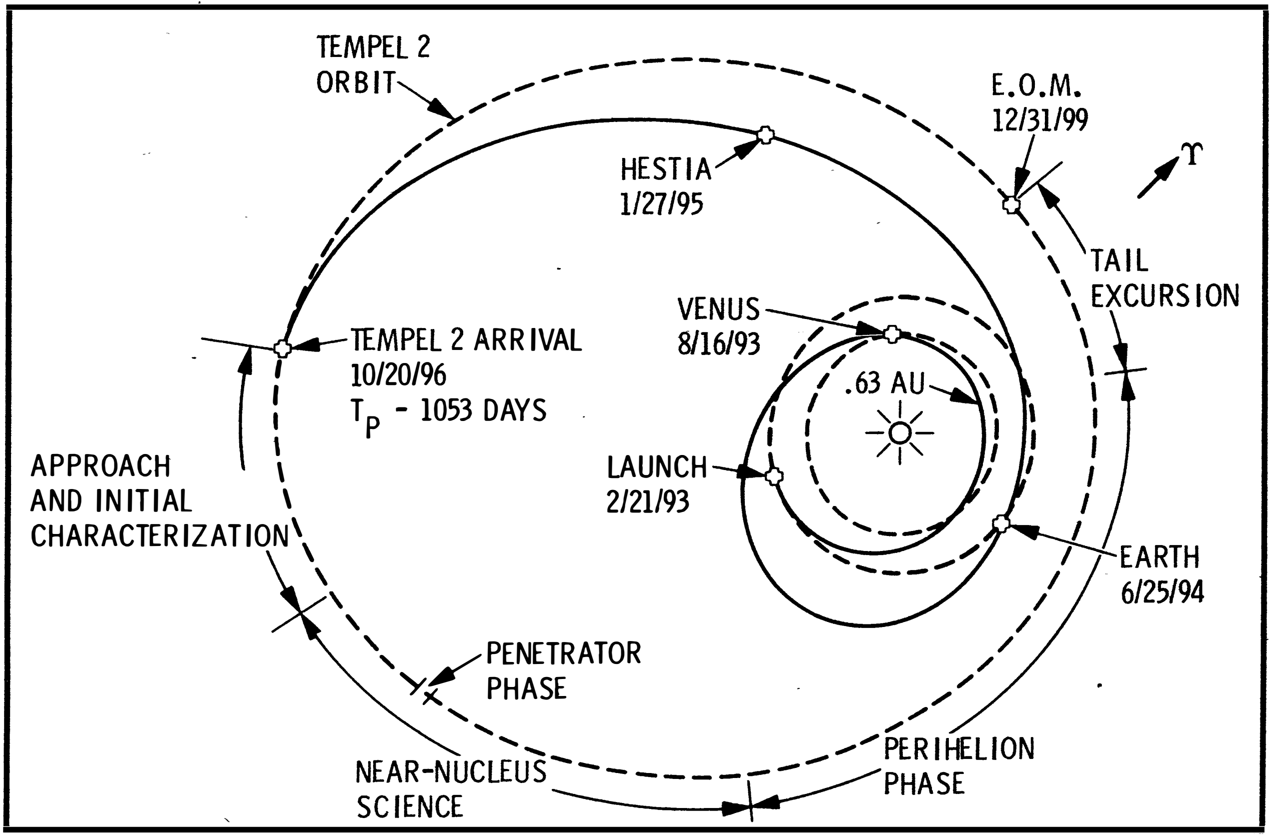
The baseline mission includes a flyby of Venus at 9000 km altitude in August 1993 in order to receive a gravity assist. The Earth would be encountered in June 1994, with a flyby altitude of only 300 km, to receive a second gravity assist. The vowel in "CRAF" would be justified in January 1995 by an encounter with the asteroid 46 Hestia (136 km diameter) for the purpose of gathering scientific data; the flyby speed is calculated to be 11.4 km/s.

Arrival at Tempel 2 is scheduled for October 1996. After rendezvous with the nucleus, at the time it will be near its furthest point from the Sun (aphelion), the spacecraft would proceed to direct the full resources of its scientific payload to a study of that pristine piece of solar system territory. Tempel 2, which has an orbital period of 5.3 years, will reach perihelion on September 8, 1999, and the CRAF nominal mission would end on December 31, 1999.

The CRAF project team has shown the ability to redesign the mission in response to several launch-date slips due to the lack of a new start, for funding reasons. Although fiscal constraints are indeed tight, the fundamental scientific importance of this mission, coupled with the exceptionally strong plan developed by the cost-conscious CRAF team, bode well for the future of this NASA project.

CRAF is managed by JPL for NASA's Office of Space Science and Applications. Ronald F. Draper of JPL is the Project Manager.

In this overview of the proposed Comet Rendezvous Asteroid Flyby (CRAF) mission, three segments of the trajectory are apparent. The first winds around the inner Solar System, with gravity assists from Venus and Earth, in order to gain energy for the second segment, the cruise to Tempel 2 (with a flyby of the asteroid Hestia). The rendezvous with the comet constitutes the third, principal, segment. *NASA/JPL*



Artificial Intelligence Research

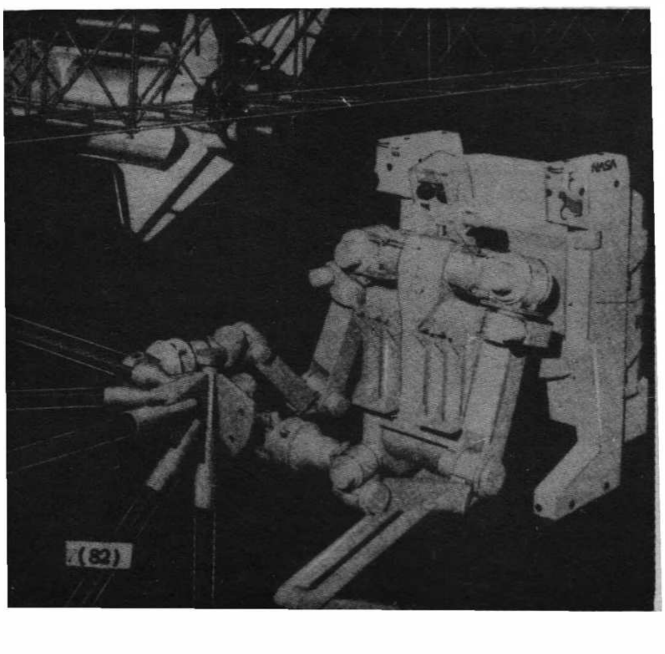
The subjects of artificial intelligence and expert systems were addressed in last month's column as they relate to applications in building spacecraft observing programs or "sequences". This month the work of a second group at JPL will be reviewed: the Artificial Intelligence Research Group, supervised by David Atkinson. The charter of the group is to bring basic research in artificial intelligence to bear upon NASA work. This objective is accomplished by identifying and adapting research done in universities and by performing basic research within the group itself.

A major thrust has been a planning and reasoning task in support of the JPL telerobot. "Telerobot" can be dissected to reveal its meaning: "tele" indicates control from a distance, such as used in "telemetry" (measurement from a distance), while "robot" implies autonomy of operation. Thus, a telerobot will have the capability to perform some tasks on its own and will be guided in others by a remotely located human operator, possibly using the sensory systems of the telerobot to gather information.

The JPL telerobot has several potential applications: in the satellite-servicing bay of the Shuttle or Space Station and as the "smart" front end of an orbital manoeuvering vehicle that would be sent to service satellites in orbit. The telerobot features two industrial robot arms and a stereovision system. In 1996, when the telerobot is fully operational on-orbit, an astronaut will be able to give the device a high-level command such as "replace the main electronics box" (on a satellite) and expect to have this job completed successfully.

The most challenging part of the planning and reasoning task for the telerobot is to build a recovery-from-error capability. Unlike industrial robots, which usually work in relatively standardised environments, the telerobot will often labour in situations complicated by uncertainty and change. For example, a tool might slip and be floating in the area. The telerobot has to be able to sense that an error has occurred, diagnose the problem in detail, and develop a plan of action to recover from the error. A second example of the type of situation that the telerobot might have to cope with was furnished by the (human) on-orbit repair of NASA's Solar Max satellite: inaccurate engineering drawings for the satellite caused problems for the Shuttle astronauts.

A Manned Manoeuvring Unit with a "smart" front end. Such a telerobot could be used for building large structures in space. *Martin Marietta*



Solar Max has been selected as a study case, and a demo in 1988 will involve the telerobot operating on a mockup of Solar Max at JPL.

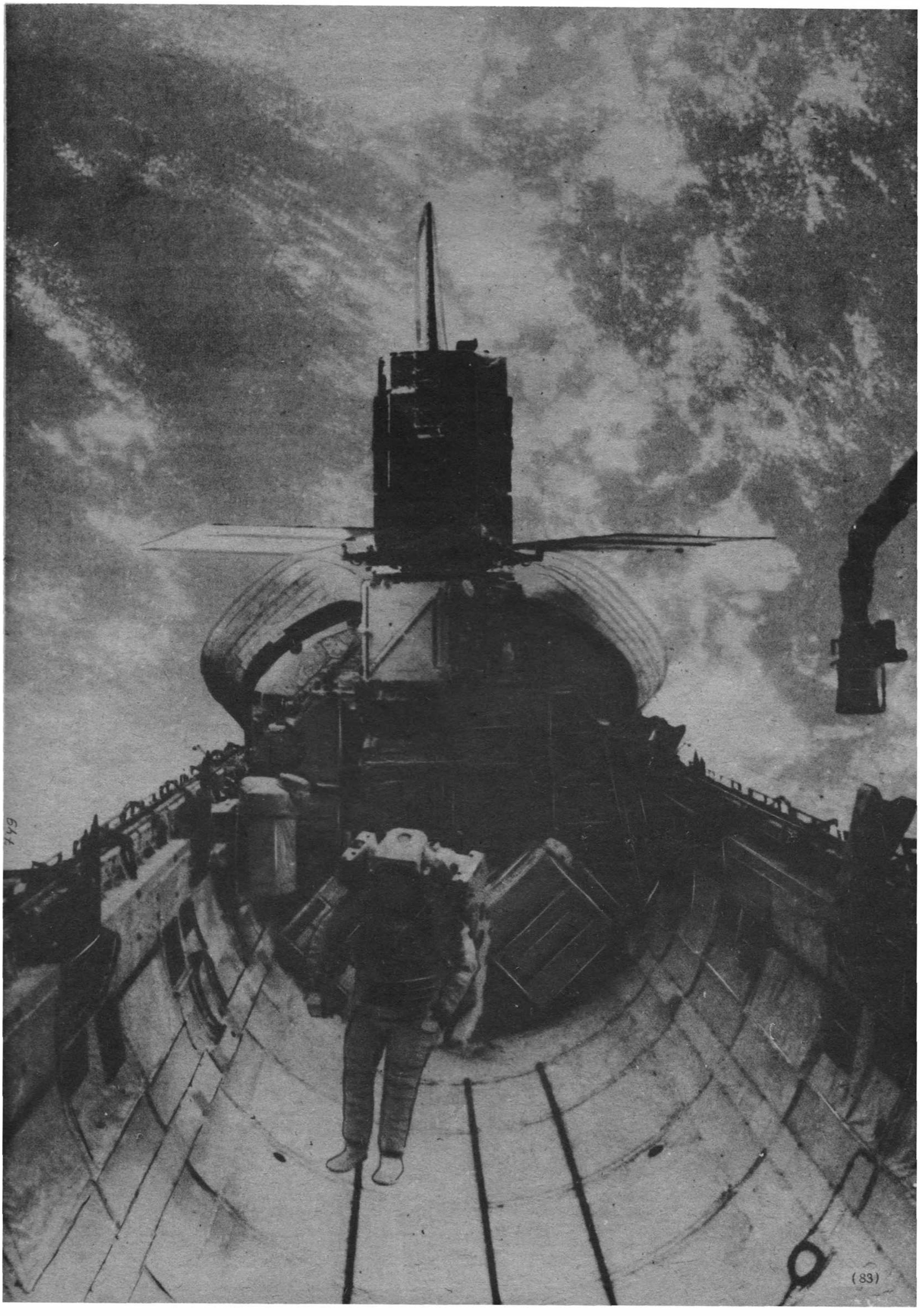
A second effort of the group is to develop route planning and navigational capabilities for a planetary rover which could figure prominently in the future exploration of Mars. The sensor for the rover is presumed to be a stereovision system. The product of the sensor will be, after some computer processing, a contour map of the region of Mars to be traversed by the rover. The robot will use this map, along with other knowledge of the terrain and robot capabilities, to find a safe path which it is able to traverse. Initial plans call for extensive human supervision of the rover over short paths. Later, more sophisticated route planning would shift more of the planning onus to the rover itself. Eventually, the system might be able to select its own long-distance routes given only its destination for guidance, perhaps, even, in such general terms as "go over to Ridge X and collect samples."

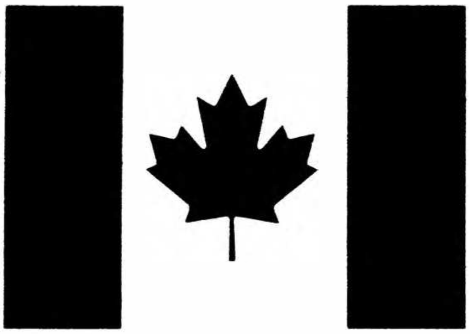
Problems often arise in planetary mission operations and need rapid diagnoses so that data loss is minimised and spacecraft safety is maximised. The program FAITH (Forming and Intelligently Testing Hypotheses) has been devised to assist humans in the act of diagnosis. The Voyager photopolarimeter subsystem was used as a model, and FAITH operated upon simulated telemetry from this instrument. The program showed the ability to diagnose 76 different types of faults in a demonstration done in 1985.

The Hypercube is a concurrent processing computer being developed at Caltech/JPL (see the April 1985 edition of "Space at JPL"). Most present-day computers operate as sequential machines – they process jobs one after the other. The concurrent processor has many semi-independent processors ("nodes") that each, at the same time, address part of the problem to be solved. The scheme has shown considerable promise in producing machines with great computing power at low cost, but it suffers the disadvantage that most computer programs, including operating systems, have been written for sequential machines. The concurrent processor has a lot of catching up to do. Filling part of this gap, Atkinson's group is developing an object-oriented programming language to work on the Hypercube. The "objects" in this case are the nodes of the Hypercube. These nodes are sent high-level instructions and then local code, within the node, takes over. In this way, a distributed planner is being constructed.

Although arguments flow back and forth through the literature of computer science as to whether or not machines will ever exhibit intelligent behaviour – and, since the argument is not complete, the term "artificial intelligence" may be premature – nonetheless, a host of useful applications is emerging from these new programming techniques, however they should be labelled.

Right: Solar Max, seen here following its retrieval in 1984, has been selected as a study case by JPL for telerobot operation.





Canadian Government Partners Space Industry

A new approach to government-industry co-operation began in Canada in 1986 with the signing of a Memorandum of Understanding by the Chairman and Chief Executive Officer of Spar Aerospace Limited, Larry D. Clarke, and the Minister of Regional Industrial Expansion, Sinclair Stevens, in Montreal.

The agreement will enable Spar to undertake the long-range research and development necessary to enhance its market position in such areas as space communications, telerobotics and electro-optics. The Government will, over the next five years, invest some $130 million in this effort, while Spar will invest $170 million.

"This historic signing recognises that government and industry have a mutual stake in our country's future in advanced technology. We welcome both the challenge and the obligation it lays on us," said Mr. Clarke.

"The essential difference in the Government's role from that in the past is that for the first time it joins us in the process – a process that commits joint financial support to research and development programmes over a multi-year time frame. Thus Spar can move ahead with the firm assurance of the financial resources that will be available to us in the pursuit of our market objectives. The Government, in turn, is given a continuing overview of the investment of public funds."

Remote Sensing by Radar

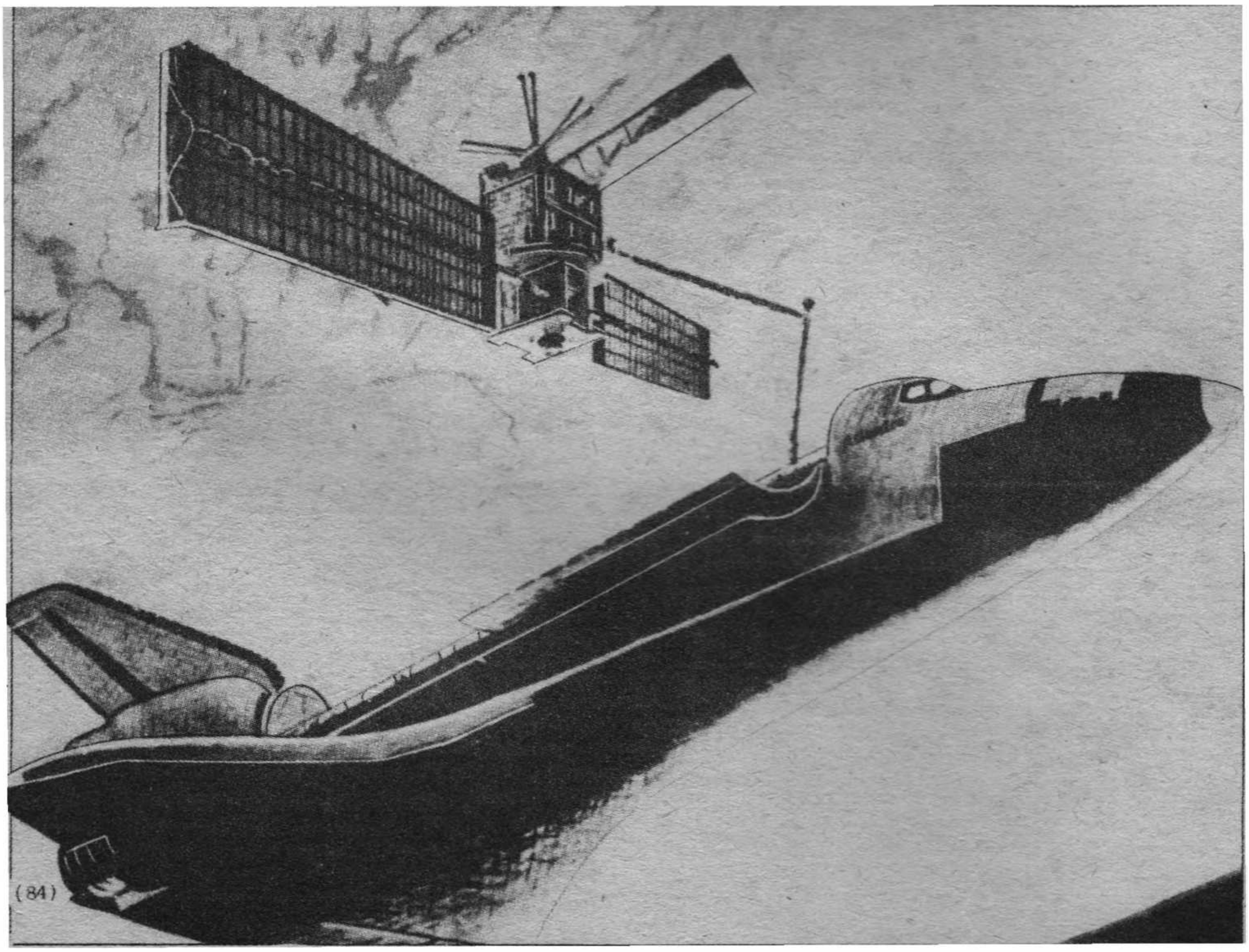
Canada's first remote sensing satellite will have the ability to see through any weather conditions when it is launched by the Shuttle into a near-polar orbit in the early 1990's.

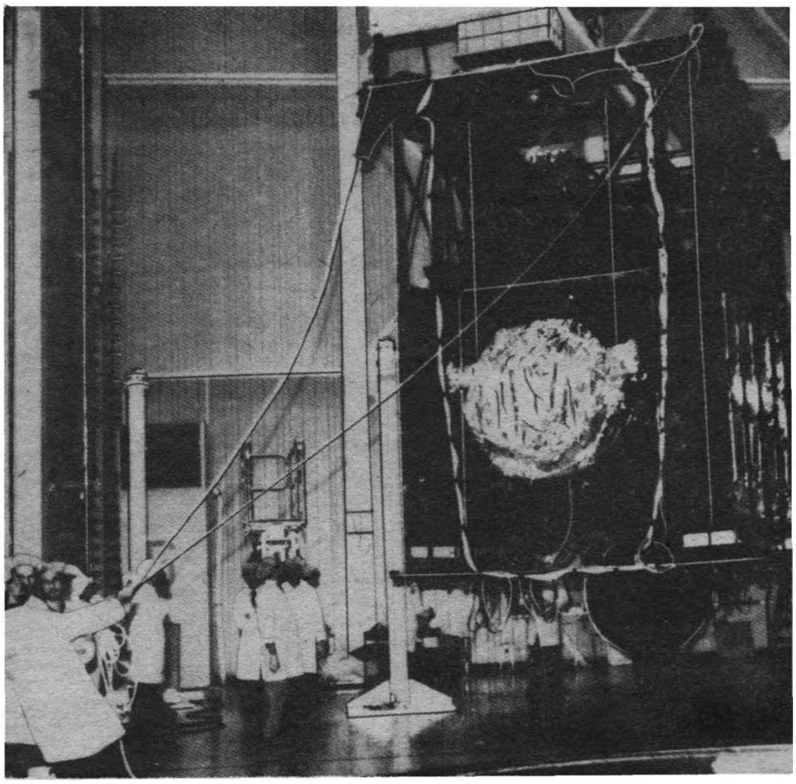
Named Radarsat, its principal instrument will be a synthetic aperture radar with six beams that can be chosen to view a swath of 130 km width between 20 degrees and 40 degrees from the nadir. The satellite will also carry multispectral optical sensors, including an advanced radiometer employed mainly to monitor soil moisture and crop conditions and a scatterometer to measure liquids over the ocean.

Engineers at Canadian Astronautics Limited (CAL) have been designing three elements of the radar – a low-power transmitter, the receiver and a calibration system for ensuring the system's accuracy when in orbit. CAL is currently undertaking the detailed design of the radar's deployable antenna which consists of five panels that are folded together during launch.

Details of the radar, recently released, are: Antenna size (deployed) 12.9 m x 1.5 m; Frequency 5.3 GHz; Bandwidth ± 15 MHz; Pulse Repetition Frequency 1200-1400 in steps of one; Power 100 W; Mass 471 kg; Life five years in LEO. Radarsat is being redesigned to allow on-orbit service by the Space Shuttle – a change that will double the satellite's lifetime.

An artist's impression of Radarsat being removed from the Space Shuttle's cargo bay by the Canadarm prior to its transportation to final orbit by an orbital manoeuvring vehicle.





Removal of the Olympus satellite thermal model following testing in a vacuum chamber. *SPAR*

Olympus Tested in Canada

Completion of environmental tests of the ESA Olympus spacecraft in 1986 at Ottawa's David Florida Laboratory (DFL) and the National Aeronautical Establishment's Ottawa facility (NAE) confirmed the versatility and effectiveness of spacecraft test facilities that are now available in Canada to satellite builders.

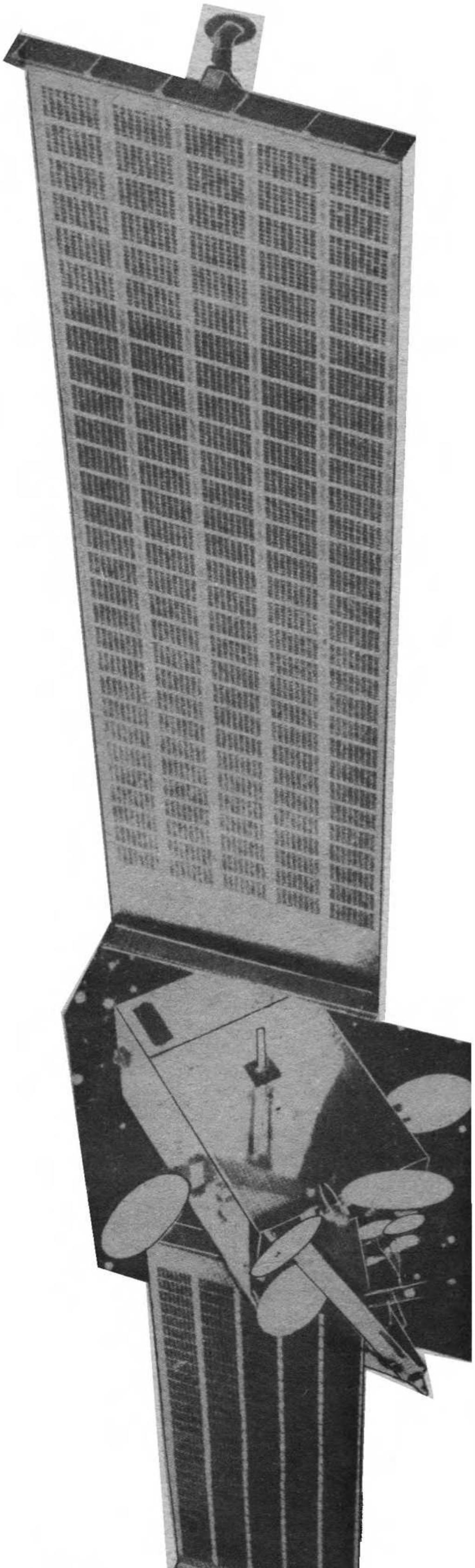
Olympus is a new generation of large European multi-purpose communications satellites whose service include direct-to-home TV broadcasting. Project definition studies were conducted during 1980 and 1981 and full development was initiated at the start of 1982. The first satellite is now scheduled for an Ariane launch in 1988.

Olympus will carry a two-channel TV payload suitable for a high-power direct-to-home broadcasting in the 11.7 – 12.5 GHz band. One channel will be employed for pre-operations services in Italy while the other will be steerable to support experiments and demonstrations over the whole of Europe. Transmission of a single 'European' programme over the whole of Europe for reception by individual and community/cable lead installation will also be provided.

The Canadian tests included structural and model vibration and acoustic testing to qualify the satellite for launch by either the Space Shuttle or Ariane. In-orbit thermal performance was tested on the thermal model using an infrared technique as a potential alternative to solar simulation testing. Various new technologies were introduced including an extremely accurate system to measure satellite temperature to within 0.2°C.

Canada, as an associate member of ESA, plays a key role in the Olympus project. Star Aerospace, besides being involved in the Olympus tests with British Aerospace, the prime contractor for the programme, is also building the extensive solar arrays in co-operation with Fokker of the Netherlands.

The other countries participating in the main development phase of the Olympus programme are Austria, Belgium, Denmark, Italy, The Netherlands, Spain and the UK. Some 40 major industrial sub-contractors are supporting the development.



Olympus communications satellite.

Pin-Pointing by Satellite

Representation of how the third generation INMARSAT satellite would cover the uneven distribution of vessels and aircraft across the Atlantic Ocean. *CAL*

NEW INMARSAT SYSTEM

A third generation satellite system is planned by INMARSAT for introduction over the Atlantic with the first launch in 1995. The projected traffic for all INMARSAT services is expected to grow from the existing 5,000 vessels in a single global beam to as many as 50,000 vessels by the year 2005 requiring as many as 61 beams.

Canadian Astronautics Ltd (CAL) is under contract to INMARSAT, whose HQ is in London, England, to perform a 'Study on Satellite Spot-Beam Configurations to provide for maximum re-use'. The extremely uneven traffic distribution across any ocean presents a challenge for conventional frequency re-use antennas.

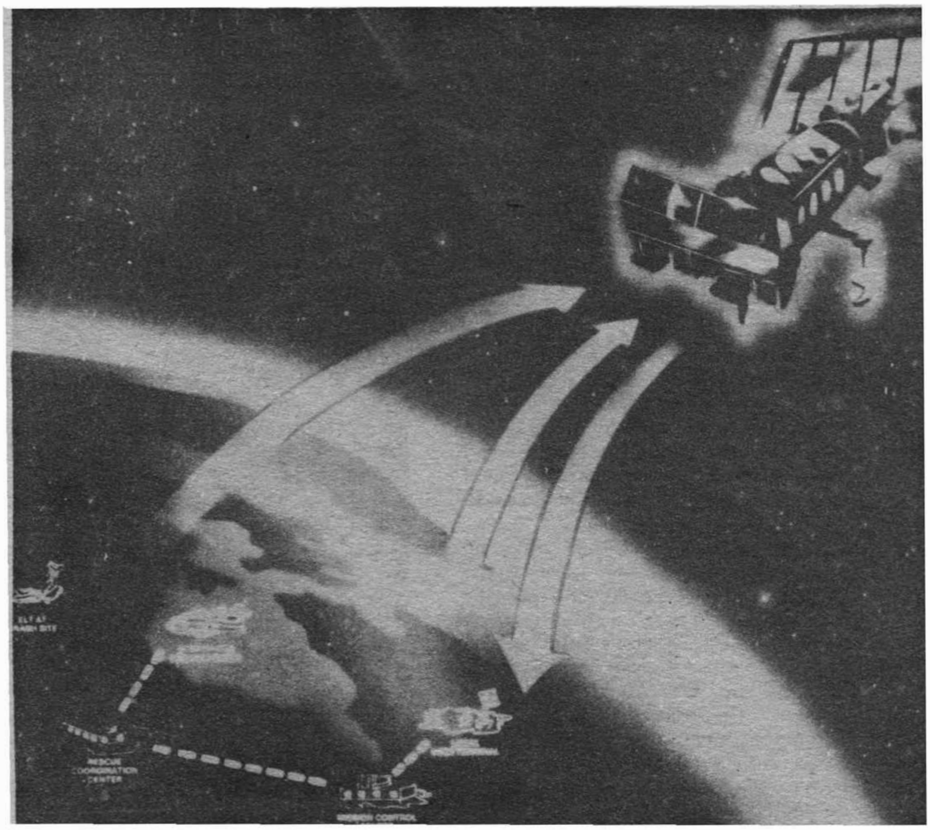
The third generation satellite system designed by CAL has been optimised for maximum channel capacity within the lower and mass limitations of available spacecraft buses and launchers. The study demonstrates that a simple spacecraft transponder with a 3.4 metre reflector antenna can handle over 50,000 vessels in a frequency re-use 5 MHz bandwidth for the spot beam (standard B) service, as well as 10,000 users of the existing spot and/or global beam (standard A) service, the small ships (standard C) service and Aeronautical services, to well beyond the year 2000.

Emergencies

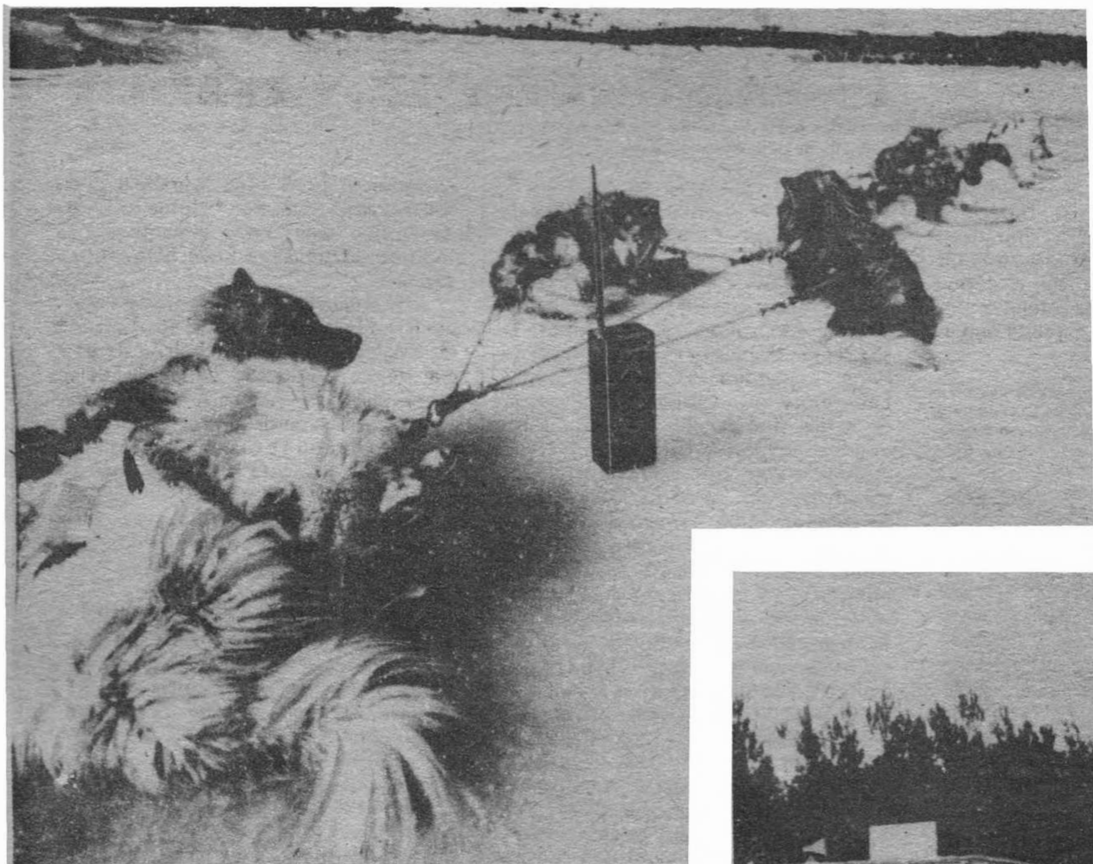
The highly successful international search and rescue satellite system, COSPAS-SARSAT, has four participating countries: Canada, France, the US and the USSR. Since the launch of the first satellite, COSPAS 1, in 1982 over 450 lives had been saved by the end of 1985 in rescue missions around the world.

All important for the early detection and recognition of emergency signals is the quality of receiving equipment at the ground station to which the emergency signals are relayed back via the satellite. The technical difficulty is caused by the general use of inexpensive, low power emergency beacons which were never designed with this type of locating in mind. The received signals are very weak, unstable and carry no identification to assist in differentiating one from another.

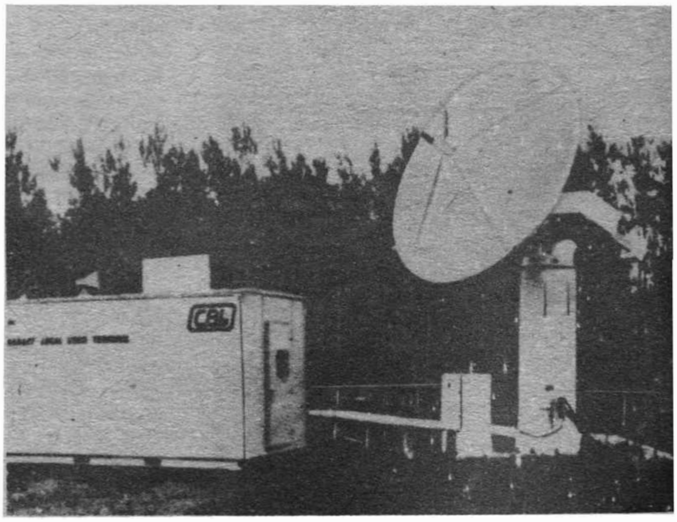
Canadian Astronautics Limited (CAL) has been an important supplier of ground station equipment with its SARSAT Local User Terminals (LUT) which have performed with a pinpointing accuracy averaging about 15 km.



Chain of communication demonstrating the capability of the SARSAT system in relaying information quickly to rescue services from a remote location. *CAL*



Left and below left: Distress signals broadcast by transmitters from remote places such as the Arctic and (below) a typical Local User Terminal which would pinpoint the origin of the signals to within an average of 15 km.



The LUT receives distress signals at the three frequencies of 121.5 MHz, 243 MHz and 406 MHz. The technological key to the system is the CAL-developed signal processing which is able to receive and process the weak and unstable signals emitted by the most common emergency transmitters operating in the 121.5 MHz band. More than 350,000 emergency beacons installed in aircraft and vessels around the world transmit at this frequency.

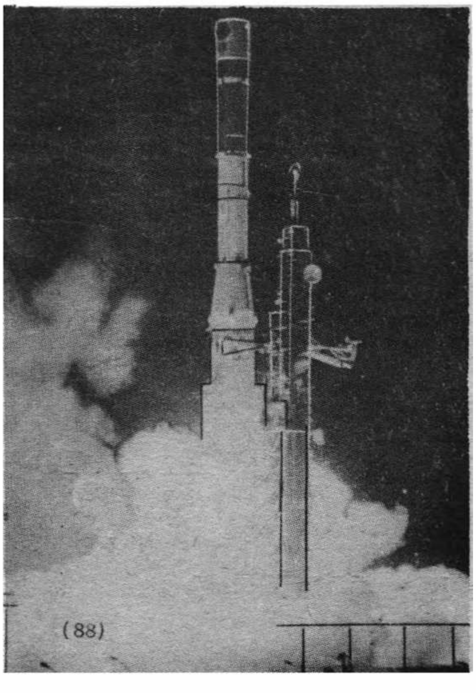
Canadian Speaks To Canadian

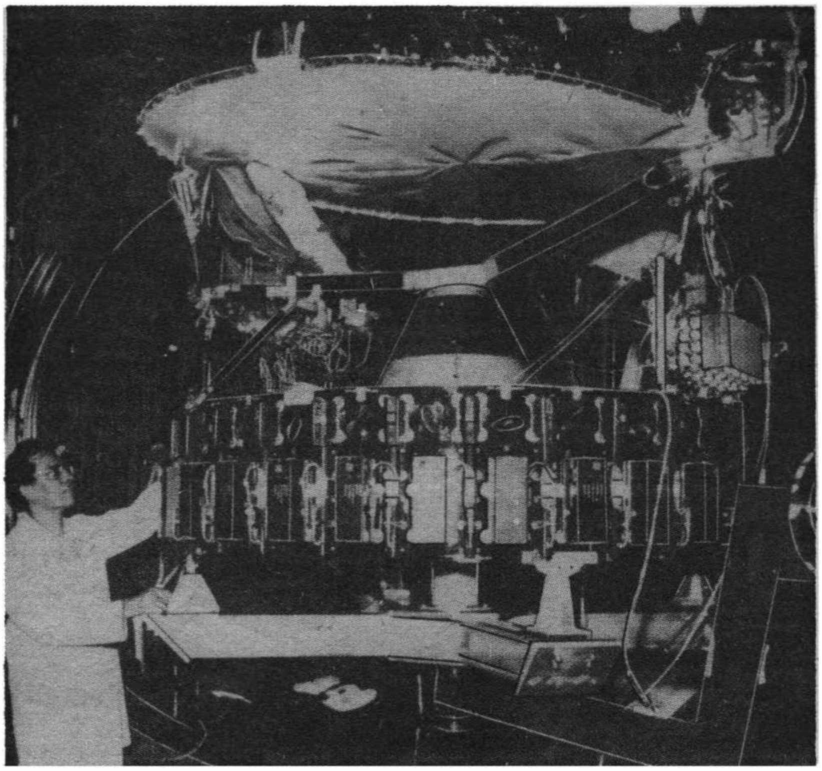
The advent of the communications satellite has proved to be a great benefit for the sprawling territories of Canada, which now has the most extensively-developed domestic satellite system in the world.

Spaceflight (July/August 1985, pp 314-317) presented the story of the early phases of this programme and its development to the present stage in an article entitled 'Canada's Satellite System' by Peter Jedicke and Clifford Cunningham. Extracts of this article provide the following information about the latest 'Anik' satellites. The name 'Anik' was chosen for Canada's own satellite hardware in a nationwide contest: it is the Inuit (Eskimo) word for 'brother'.

Anik C was the first satellite of this series to apply the mid-1970's technology to meet the requirements of a domestic communications satellite system. Three models were constructed by Hughes with substantial subcontracting to Canada's Spar Aerospace Limited. When the third one, Anik C3, was ready so was the Space Shuttle: and in order to minimise the expense of moving satellites into and out of storage, Anik C3 was launched first. The Anik C series are 16-channel 14/12 Ghz satellites and are the mainstay of TV satellite use in Canada.

The first Brazilsat communications satellite launched from Kourou by Ariane V12 on February 8, 1985. This and a second Brazilsat, launched by Ariane in March last year, were built by Spar Aerospace. Canada.





Integration and testing of the Canadian-built Brazilsat communications satellite by Spar Aerospace at the David Florida Laboratory in Ottawa. *SPAR*

The two spacecraft of the Anik D series have 24 channels in the 6/4 GHz band and will replace earlier Aniks. Spar Aerospace assumed the role of prime contractor for these satellites – a major responsibility for a Canadian company to undertake. Also for the D series, the Department of Communications expanded its David Florida Laboratory at Ottawa to become Canada's first facility for integrating and testing large satellites.

Anik D was launched from Orbiter Discovery on Mission 51A on 9 November 1984 (***Spaceflight***, June 1985, p 260). Before it was released, the orbit was circularised at 302 km altitude by two engine burns. Checkout of the satellite went well and as Discovery crossed the equator, the spinning drum-shaped spacecraft was ejected from the payload bay exactly as planned. As soon as the Orbiter was at a safe distance, some 45 minutes after deployment, the solid-propellant motor was fired to push Anik into a geosynchonous transfer orbit. The perfect 87 second burn set the satellite up for its eventual positioning over the equator at 111.5°W longitude. Anik was put into storage at this location to wait until 1986 to come into full service. Telesat Canada, the owners, took such an unusual step after deciding it would cost less to launch the spacecraft in 1984 and store it in orbit for two years than it would cost to launch it in 1986 at increased Shuttle prices. In view of the curtailment of Shuttle launches and the increase of launch failures in 1986 the move was more advantageous than could possibly have been foreseen.

A considerable investment has been made in Earth station equipment for linking satellites with their commercial users. Command and control is accomplished from a central control in Ottawa, which communicates with the satellites through a major Earth station at Allan Park, Ontario. At the same location is one of the two prime Earth stations for the Canadian system, the other one being at Lake Cowichan, British Columbia. Each of these stations has a 30 m antenna and provides a trunk message service across southern Canada. Another station on the east coast at Mill Village, Nova Scotia provides Teleglobe Canada's links to the international system. Over 100 smaller stations, with antenna up to 10 m in diameter, are situated at various locations around the country

In their entirety, Canadian telecommunications form a vast grid stretching across land and water from the east to west coasts, with branches north and south and extending into virtually every community. The network consists of open wires, cables, microwave systems, the domestic communications satellites and a vast array of different types of switching facilities that are able to link everything from telephones to computers.

MARCH 1987 $3.00 £1.25

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- Targeting NEPTUNE
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DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone 0344-884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.** 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by Unwin Brothers Ltd., Old Woking, Surrey, England.

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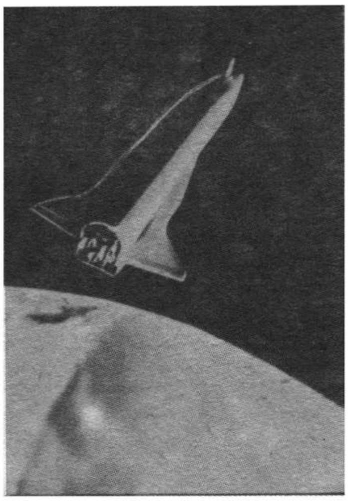
Vol. 29 No. 3 March 1987

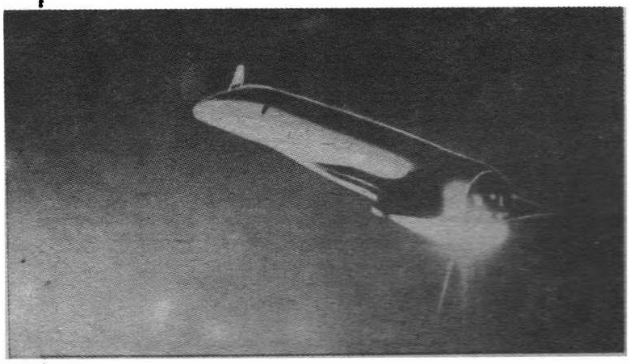
Front Cover: Lift-off of a Soyuz night-time launch. Soyuz has been the work-horse of Soviet manned space flight since 1967. The original Soyuz series was phased out in 1982 following the introduction of the improved Soyuz T series in 1979. Further improvements have culminated in the Soyuz TM series of increased man-carrying payload, which can communicate with the Earth via a relay satellite and can also dock at the lateral ports of the Mir space station (p.104). The first Soyuz TM was launched unmanned on May 21, 1986 as a test mission. On February 5, 1987 Soyuz TM-2 was successfully launched with cosmonauts Yuri Romanenko and Alexander Laveikin on board.



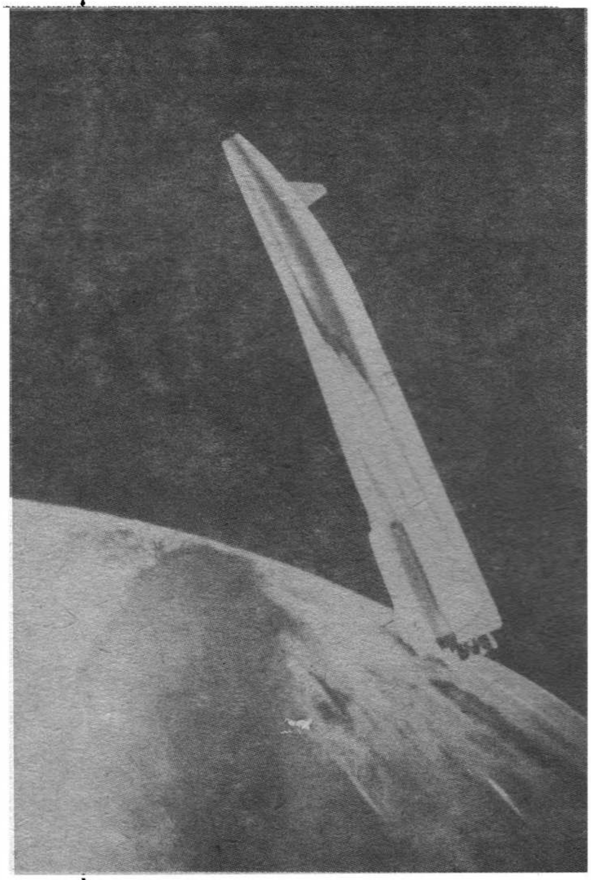
HOTOL: *Jumbo Jet Launch Proposal*

Sir, I am writing to propose an alternative means of launching Hotol – by launching it from a modified Boeing 747 jumbo jet.

Risks are involved with Hotol's current launcher trolley and there could be scaling and/or payload advantages using an air launching technique.



After reaching orbit, the atitude can be changed as required to meet mission objectives. A high incidence, as shown below is adopted at the start of re-entry.



A specially developed aircraft would certainly cost several hundred million pounds to design and produce. However, I suggest that the trusty old Boeing 747 could do the job.

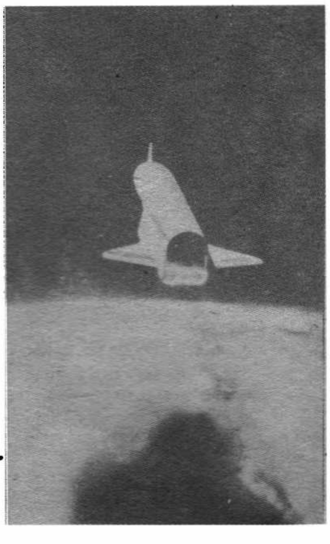
At present the case is marginal as the current take-off weight of Hotol is quoted at 230 tons and the current maximum take-off payload of a Boeing 747, including fuel, is about 233 "short" tons. But, by the time that Hotol is likely to be developed, the next generation of Boeing 747s – the series 500, which will have a much larger wing and new ultra high bypass engines – should be available. A stripped down version of this aircraft should be able to take-off with a fully fueled Hotol and be able to cruise to a sufficient altitude to air-launch Hotol successfully.

The next question is – could Hotol physically be fitted on top of a Boeing 747, in a similar fashion to NASA's shuttle carrier aircraft, bearing in mind that Hotol is somewhat larger than the Shuttle? After an initial sketch, which showed that it might fit – I decided to make a 1:144 scale model of "my" proposed Boeing 747/Hotol and I should here stress that "my" Hotol is unofficial and based only on published information.

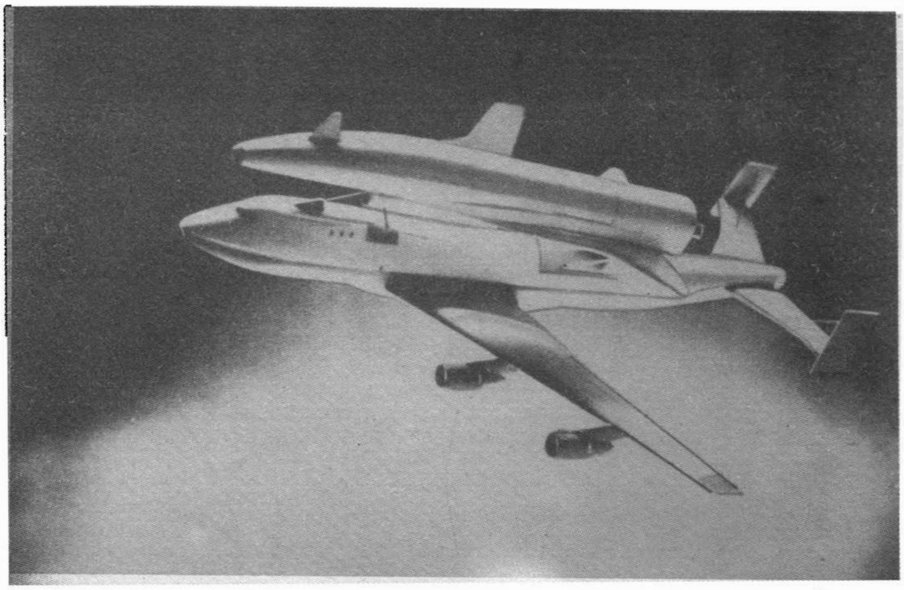
In my design I have completely removed the Boeing's tailfin as it would probably be destroyed by Hotol's exhaust and would also present a severe fouling hazard during the in-flight launch separation manoeuvre. The twin tailfins are thus larger than on the NASA 747.

Thus, provided that there are no insuperable aerodynamic or c.g. objections to the idea the Boeing

The climb to orbit is powered by a hybrid engine which initially uses atmospheric oxygen before switching over to onboard oxygen as the rarer atmosphere is reached.



Model-maker *Bernard Carr* proposes an alternative means of launching Hotol and illustrates his ideas with models and this spectacular series of photos.



The Boeing 747/Hotol combination climbs to altitude. The aircraft shows a close similarity with the NASA 747 used to carry the Shuttle, the single tailfin being replaced by twin tailfins. The scheme has other applications than that of launching Hotol – as a ferry from factory to launch site or for retrieval from an emergency launching site.

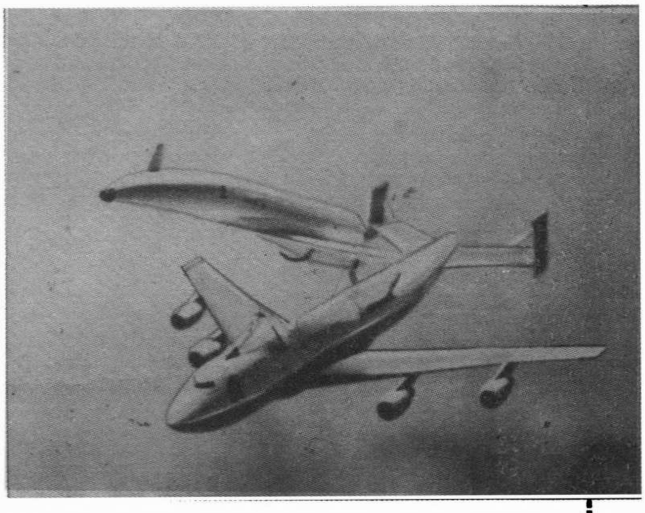
747/Hotol combination could serve any or all of the following functions.

1. As a ferry – Hotol will need to be ferried from factory to launch site – and on occasion may have to be "retrieved" from a diversionary or emergency landing site.
2. As an air-launcher for initial flight and landing tests similar to those of the early Shuttle "drop" tests.
3. As an actual air-launcher for fully fueled Hotol orbital missions.
4. If '3' above proves impracticable – why not simply use the Boeing 747 carrier as a "trolley" itself (i.e. thundering down the runway with Hotol on its back – but with the Boeing not taking off itself)?.

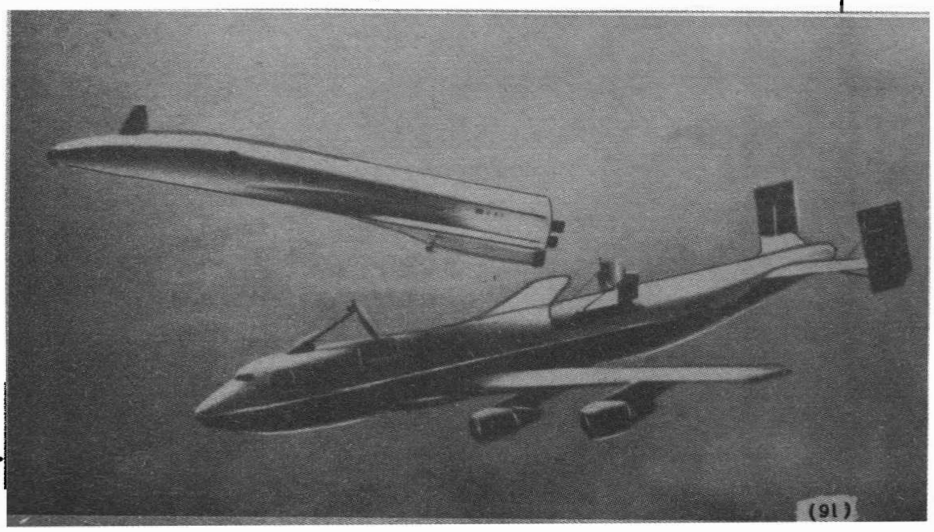
In conclusion, the Boeing 747/Hotol combination could offer several benefits; chief among which are, the possibility of scaling Hotol down – due to a lower take-off fuel requirement, or alternatively an increased payload capacity especially valuable for future more ambitious missions.

As a final aside – might it also be possible to fit a Liquid Hydrogen/Liquid Oxygen separation plant into a second converted Boeing 747. The pair of Boeings would then provide Hotol with a truly flexible launch capability being independent of any particular launch site.

BERNARD CARR
Surrey, UK.



The moments following separation.



CORRESPONDENCE

Copernican Heliocentric Theory

Sir, I cannot fully agree with the comments in your 'Space at JPL' report (***Spaceflight***, January 1987, p. 43) that lack of stellar parallax still counted against heliocentric theories etc. etc.

Bessel merely confirmed what had long been accepted in leading astronomical circles ever since James Bradley (third Astronomer Royal) published his findings in 1728, 110 years before Bessel published his work on 61 Cygni.

Bradley carried out accurate measurements on several stars (principally γ Draconis) commencing serious work in November 1725. By March 1726 he had already detected a shift of 20 arc seconds, and prophesied that it (γ Draconis) should return to its original position by November 1726 – and it did!

In 1728 Bradley published and gave a detailed account to Edmund Halley (then the Second Astronomer Royal) subsequently to be printed in the Royal Society's Journal "Philosophical Transactions" (No. 406 vol. XXXV page 637).

Bradley knew that any real parallax would be small for, having measured the aberration constant as being 20" and 20.5" (today's figure is accepted as 20.47") he went on to say: "I am of the opinion that if it were 1" I should have perceived it." In fact the modern accepted parallax for γ Draconis is 0.017". Bradley also knew that he had *not* measured parallax for the observed shift was 90 degrees out of phase of the expected parallax effect.

At the end of his letter to Halley he stated: "There appeared therefore after all no sensible parallax in the fixed stars, the anti Copernicans have still room on that account to object against the motion of the Earth; and they may have (if they please) a much greater objection against the hypothesis by which I have endeavoured to solve the aforementioned phenomena, by denying the progressive motion of light, as well as that of the Earth . . . I do not apprehend that either of these postulates will be denied me by the generality of the astronomers and philosophers of the present age."

This was a real backhanded slap in the face for the anti-Copernicans, for Bradley was quite right – he was not "denied", and his postulates were accepted as proof of Copernican heliocentric theory and also that the velocity of light was finite.

In the course of current extra mural research on the memories, life, and works of Bradley, I have always been impressed by his concise statements of facts as he observed them, and the expressed simplicity with which he drew his brilliant conclusions.

Bessel drew on Bradley's observations for much of his own work and in 1818 published the reduced tables for 1750-1762 whose average errors were less than 4" in declination and 15" in right ascension. Bessel was very impressed and said so.

Because his observations were so accurate, Bradley's work is of considerable value today, particularly if long term stellar movements are involved such as proper motion of single stars or orbital motion of double or multiple stars over a period of approximately 250-280 years.

In summary, Bradley killed pre-Copernican planetary theories, Bessel just buried them!

A.T. LAWTON
Shepperton, UK

Soviet Launchings

Sir, I note that David Anderman (***Spaceflight***, December 1986, p.417) asks for identification of a particular oceanographic satellite launched from Plesetsk. The satellite in question is almost certainly Cosmos 1766 since it was announced in a *Tass* release as an oceanographic vehicle and was launched on July 28, 1986. That also says that Robert Christy's ID of Cosmos 1766 as an Elint class craft is incorrect. There have been a number of oceanographic craft whose orbital parameters are, for all practical purposes, identical to those of the 82.XX degree Elint spacecraft. In many – if not all – cases there have been *Tass* announcements identifying them. (*Ed.* – Robert Christy issued an 'Update' on Cosmos 1766, which appeared in the February issue of ***Spaceflight*** prior to the receipt of this letter).

Coincidentally, I would like to take issue with David Anderman's analysis, "Soviet Orbital Masses" (***Spaceflight***, January 1987, p.16). While, regrettably, I am unable to locate it I have in my data bank a Soviet paper clearly noting that the mass of Meteor satellites is only 1237 kg (2727 lb). The use of the Vostok (or Soyuz) booster to place so small a spacecraft in orbit compared to the capabilities of those boosters is, to say the least, wasteful of resources. In the area of space activity I am convinced the Soviet Union does not use its resources in such a manner. While the first three Sputniks used the sustainer and strap-on mode of the Vostok booster only because that was the only launch vehicle available, by the time the Meteors came along there were several boosters tuned to its needs for launching.

Vostok uses a much smaller upper stage than does the Soyuz booster and the difference in the capabilities is apparent enough: 4635 kg in orbit for the Vostok, and 7030 kg for the Soyuz version. The former is well represented by the Vostok spacecraft (the weight is now used regularly for reconnaissance craft of an earlier generation) and the latter, of course, for launching the Progress, Soyuz and other spacecraft in the same weight class. A more likely launcher for the Meteor is the F-2 whose capabilities probably range to 2000 kg, depending on the orbit selected.

The Vostok stage does not enter orbit at ". . . a higher altitude than its payload". What happens is the payload and stage separate and then the remaining propellant, slowly evaporating out through the nozzle, yields a small thrust that brings the stage into a slightly higher orbit. This phenomena was observed in all the flights Vostok 1 to 6.

SAUNDERS B. KRAMER
Maryland, USA

CORRESPONDENCE

Soyuz Note

Sir, The theory of Mr. Phillip S. Clark [1] that the Soyuz capsule was based on the 1960-61 General Electric Apollo proposal "D-2" is corroborated by a more detailed sketch [2,3] which gives dimensions.

It shows that as in the Soyuz, whose crews apparently descend to their couches by foot straps, launch pad entry to the D-2 was planned through a hatch in the orbital module. As in Korolyov's 1962 plans [4,5], but differing from the final Soyuz, a space traveller is shown sitting transversely to the spacecraft axis. At the bow of the orbital module is a bulky television camera to view him, equivalent to the location in the Soyuz.

But no periscope nor provision for docking mechanism was made in the D-2; the only porthole is in the orbital module. Unlike both the Soyuz and the final Apollo, the parachutes are forward of the cosmonauts' feet, indicating that they would have re-entered heads-up. And like several of the Apollo proposals [6], lift for the nine-degree blunted cone re-entry module was planned to be improved by flaps. Soyuz has a 7.5 degree blunted cone, even more internally space-efficient.

FRANK M. SOBOLEWSKI
Mass., USA

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2. Butz, J.S., Jr. "What are the Lessons of Vostok?" *Air Force*, March 1962, 36 et seq.
3. "GE Apollo Mockup and Configuration Detailed," *AW&ST*, Jan. 1, 1962, p.19.
4. Keldysh, M.V., ed , "The Creative Legacy of Academician Sergei Korolyov", Nauka Publishers, Moscow, 1980.
5. Wachtel, Claude. "Design Studies of the Vostok-J and Soyuz Spacecraft," ***JBIS***, Vol. 35, 92-94
6. "Apollo Spacecraft Chronology, The." NASA SP-4009. Scientific and Technical Information Division, Office of Technological Utilization, NASA: 1969 Vol 1., p.90. (cf. p.72).

Soyuz 4/Soyuz 5 Launch Times

Sir, In 1969 the Soviet Union announced launch times of 07.39 and 07.14 GMT for the Soyuz 4 and Soyuz 5 spacecraft, launched on 14 and 15 January respectively. These launch times seem to be in error.

Calculations using the "Two-Line Orbital Elements" prepared by NORAD suggests that the launch times were actually 07.29 and 07.05 GMT, with an expected error in the calculations of one minute. So, what are the times announced by the Soviets? From subsequent missions, the interval between launch and orbital injection is nine minutes, so it would seem that for Soyuz 4 and Soyuz 5 the Soviets announced the times of orbital injection, not the true launch times.

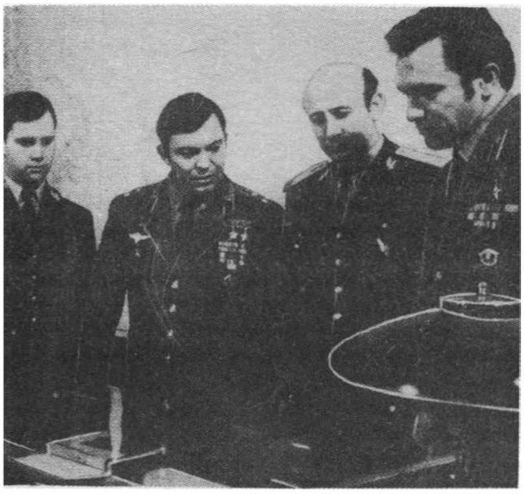
The same type of calculations based upon the "Two-Lines" confirms the landing times of 06.53 on 17 January and 08.00 on 18 January (both GMT), giving flight times of 2d 23h 24m for Soyuz 4 and 3d 0h 55m for Soyuz 5 when using the calculated launch times. The recent encyclopaedia edited by V.P. Glushko gives lifetimes of 2d 23h 21m and 3d 0h 54m for these missions. The Soyuz 5 duration is a minute in error – the error bound claimed for the calculated launch time figures – while that for Soyuz 4 differs by three minutes. If the Soviet launch times were to be used, the errors would be seven minutes (Soyuz 4) and eight minutes (Soyuz 5).

P.S. CLARK
London

Surviving Re-Entry

Sir, What would happen to a piece of paper or metal foil ejected from the Space Shuttle in low Earth orbit? Would it burn up on re-entry or simply drift down to Earth?

NEIL ROGER
Canada



Soyuz 40

Sir, The accompanying picture which was included in my report on the meeting with cosmonaut Viktor Savinykh (***Spaceflight***, January 1987, p.17) is especially interesting. It not only depicts the two cosmonauts who actually flew the Soyuz-40 mission (Dumitru Prunariu extreme left, Leonid Popov extreme right), but also the two other cosmonauts who trained as part of the Soviet-Romanian flight (standing in between Prunariu and Popov): these are Soviet commander Yuri Romanenko and Romanian would-be spaceman Dumitru Dediu.

It is widely believed that Romanenko and Dediu were the flight crew, but had to be replaced by Popov and Prunariu (the back-ups) due to a medical or technical problem which cropped up just hours or days before the scheduled launch. Yuri Romanenko had reportedly been a last-moment choice himself, bumping Valeriy Bykovskiy and/or Yevgeniy Khrunov very late in the training process [1].

Incidentally, Viktor Savinykh is now back on active duty, training as back-up flight engineer for the Soviet-Syrian space mission to Mir, which is tentatively set for launch on July 22, 1987.

BART HENDRICKX
Belgium

Reference
[1] ***Spaceflight***, June 1984, p 278-279

Ed. *The appearance of Yuri Romanenko in the above photograph has gained a new topicality with the launch of Soyuz TM-2 on February 5, 1987 as he is its mission commander.*

Early Arrival

Sir, You might be interested to know that I have received my January 1987 issue of ***Spaceflight*** by January 21, only a few days after arrival of the November issue. The newly introduced accelerated method of dispatch certainly does represent a vastly improved service to this part of the world and accordingly I would like to thank you for the initiative shown in this matter.

R.G. COOPER
Melbourne, Australia

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Launch Success for UK-Japan Satellite

The Japanese Astro-C satellite was launched successfully from the Kagoshima Space Centre at 6.30 UT on February 5 by an MU III S rocket, thereby placing in orbit the largest satellite-borne X-ray detector yet flown.

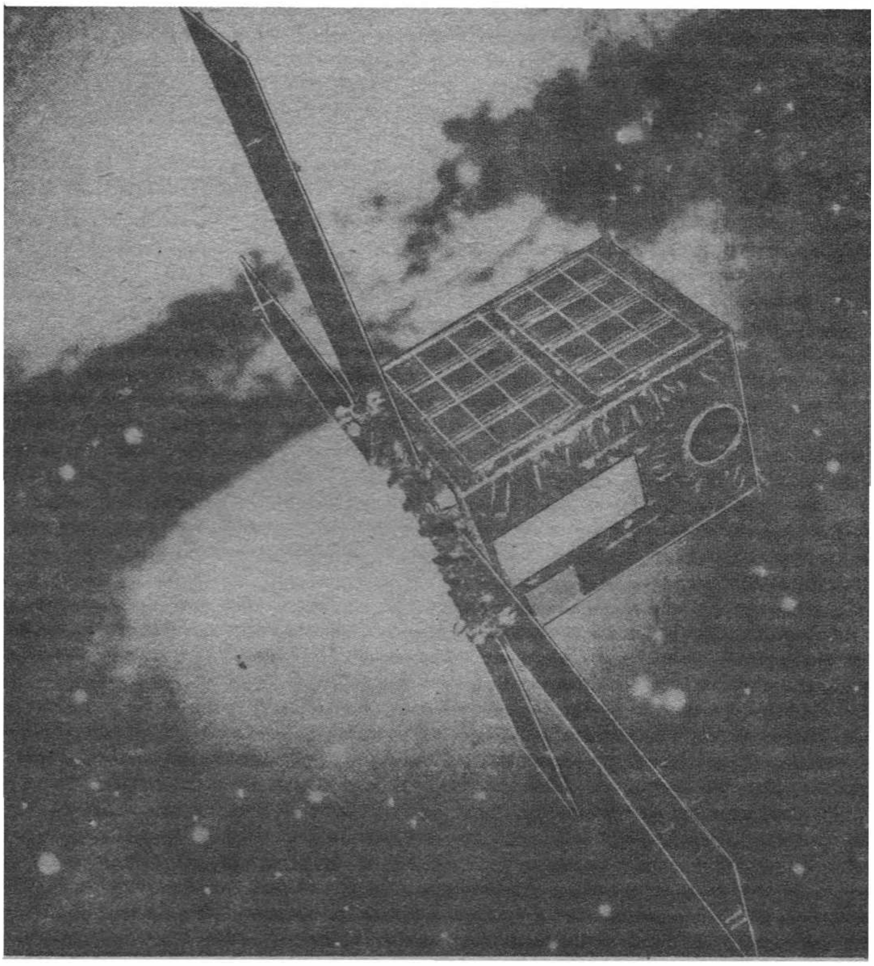
Weighing over 100 kg and with a sensitive area of a half square metre, the Large Area Counter (LAC) will study some of the most powerful objects known.

It has been developed through international collaboration between research groups at the Tokyo Institute of Space and Astronautical Science (ISAS) and the University of Nagoya, and at the University of Leicester and the Rutherford Appleton Laboratory of the Science and Engineering Research Council.

The satellite, now re-named Ginga (roughly translated from the Japanese as "galaxy"), was placed into a slightly more eccentric orbit than planned with an apogee of 670 km and perigee of 505 km. However, this is not expected to adversely affect experimentation or the orbital life-time of at least five years.

The LAC main observation programme will begin in September following three months of calibration and two months performance verification.

LAC's high sensitivity will allow X-ray signals to be monitored with greater precision than ever before, revealing important new information on the nature of emitting objects.



The Astro-C satellite superimposed on an artificial sky background. The eight X-ray counters are on the upwards pointing face.

Previously, hundreds of bright cosmic X-ray sources, discovered with earlier satellites such as Ariel 5 and EXOSAT, have been identified with binary star systems and quasar-like galaxies. A common feature of many, if not all, of these most powerful X-ray sources is that they contain a region of extreme gravity. Almost certainly this strong gravitational field is due to a neutron star or (in the case of the quasars) a very massive black hole. Dust, gas, or even whole stars, pulled into these "gravity wells" cause the release of the observed x-radiation.

Despite the large distance separating Japan and Britain, the four research groups involved with LAC have been able to work together as a single design and development team.

Once the instrument design had been completed development and manufacture of the component parts was divided between Japan and Britain in a manner which used most effectively the past experience of the team members. Accordingly the X-ray detectors and their analogue signal processing electronics were built in Britain, the advanced digital data processing unit was built in Japan, and the Japanese groups also dealt with the engineering interfaces between the instrument and the satellite.

The flexibility and open communication fostered by the single group structure, backed up by frequent exchanges of scientists between the collaborating institutes, contributed greatly to the timely completion of the instrument within the unusually short four year development schedule.

The British part of the programme was funded initially by the Science and Engineering Research Council and now by the British National Space Centre. Predominant use of small companies has proved to be advantageous in respect of low development costs, greater flexibility in the instrument procurement schedules and transfer of scientific expertise into companies which are relatively new in the field of space technology.

SATELLITE DIGEST – 200

Robert D. Christy

Continued from the February 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1790, 1986-85A, 17056.

Launched: 1150, 4 November 1986 by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 228 x 282 km, 89.64 min, 72.87 deg.

COSMOS 1791, 1986-86A, 17066.

Launched: 0611, 13 November 1986 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 954 x 1013 km, 104.83 min, 82.95 deg.

COSMOS 1792, 1986-87A, 17068.

Launched: 1100, 13 November 1986 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 173 x 335 km, 89.60 min, 64.90 deg, manoeuvrable.

POLAR BEAR, 1986-88A, 17070.

Launched: 0024* 14 November 1986 from Vandenberg AFB by Scout.
Spacecraft data: Re-furbished "Transit" type satellite, with the navigation beacons replaced by an experiments package. The mass is 125 kg.
Mission: Auroral studies.
Orbit: 963 x 1019 km, 105.00 min, 89.56 deg.

MOLNIYA-1 (69), 1986-89A, 17078.

Launched: 0935, 15 November 1986 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 460 x 40796 km, 736.12 min, 62.85 deg, then lowered to 469 x 39891 km, 717.89 min, 62.86 deg to ensure daily repeats of the ground track.

GORIZONT 13, 1986-90A, 17083.

Launched: 0208, 18 November 1986 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad.

Orbit: Geosynchronous above 90 deg east.

COSMOS 1793, 1986-91A, 17134.

Launched: 0009, 20 November 1986 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 584 x 39337 km, 709.00 min, 62.97 deg, then raised to 613 x 39739 km, 717.73 min, 62.98 deg to ensure daily repeats of the ground track.

COSMOS 1794-1801, 1986-92A-H, 17138-17145.

Launched: 0200, 21 November 1986 from Plesetsk by C-1.
Spacecraft data: Each satellite is probably spheroidal in shape, about 1 m long and 0.6 m diameter, and with mass approx 40 kg.
Mission: Single launch of eight satellites to provide tactical, point to point communications for troops or units in the field.
Orbit: 1386 x 1471 km, 114.46 min, 74.02 deg (lowest), 1467 x 1501 km, 115.67 min, 74.02 deg (highest).

COSMOS 1802, 1986--93A, 17159.

Launched: 2143, 24 November 1986 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 963 x 1025 km, 105.05 min, 82.94 deg.

UPDATES

1986-62A, COSMOS 1771 – the nuclear power source was separated from the satellite and boosted to a 916 x 998 kilometre orbit on 15 October.

1986-64A, COSMOS 1773 re-entered, possibly for recovery, on 21 October 1986.

First Commercial Contract for Chinese

China has secured its first firm contract for the launch of a commercial satellite. The country's Long March 3 booster will be used to put Western Union's Westar 6S communications satellite into geostationary orbit early next year.

Westar 6, one of two satellites retrieved by the Shuttle in 1984, is now owned by Pan Am Pacific which has also been negotiating with the Chinese for use of a Long March rocket.

INTERNATIONAL SPACE REPORT

SIX LAUNCHES FOR 1987

The first of six launches planned by NASA for 1987 using the Delta, Atlas Centaur and Scout expendable rockets was due to take place during February.

The GOES-H Weather satellite was scheduled for launch aboard Delta 179 for the National Oceanic and Atmospheric Administration (NOAA) on February 19.

On March 19, Delta 182 is scheduled to place Palapa B2-P into orbit for the Indonesian government. It is the latest in a series of communications satellites.

At the end of this month the Fleet Satellite Communications (Ftlsatcom) F-6 spacecraft is due to be put aloft aboard Atlas Centaur 67. This is a continuation of the programme to place a set of three second generation communications satellites into orbit for the US Navy. The first in the series was launched in December 1986 and F-6 had originally been planned for launch in late February.

Launch of the Fltsatcom F-8 spacecraft on May 21 will bring to a conclusion the Atlas Centaur programme under NASA operation.

During the latter part of the year a military strategic Defense Initiative (SDI) launch is planned. It will be the second of four Delta launches in this SDI series.

This year will also see a Scout launch from Vandenberg Air Force Base in September carrying a pair of navigation satellites for the US Navy.

NASA FY88 BUDGET

President Reagan requested $9.5 billion in funding for NASA in Fiscal year 1988, a budget which includes $3.7 billion for the Space Transportation System and $767 million for the Space Station.

It represents a modest increase in real terms over the $10.5 billion in the FY 1987 operating plan, which includes $2.1 billion to fully fund a replacement orbiter for Challenger.

The budget also includes authority for NASA to add 625 people to its workforce, bringing the authorised complement to 22,425.

Another feature of the budget is authorisation for Johnson Space Center to proceed with construction of a $15.8 million addition to the Mission Control Center and a $3.4 million addition to a simulator and training facility.

A four-story building is planned for construction in FY 1988, housing a "mission control centre" for the Space Station. The 90,000-square-foot addition will house the central control room and related support facilities, designed to support around-the-clock Space Station operations beginning with the Station assembly phase.

NASA Administrator James C. Fletcher said the funding for Shuttle includes money to continue activities to correct defects in the solid rocket booster and to improve other elements of the STS; to conduct flight missions; to continue implementation of the Rogers Commission recommendations; to do work necessary to procure upper stages for Shuttle-launched science missions and for other activities.

The $767 million requested for the Space Station will provide for the phased build-up of developmental activities consistent with the programme review undertaken in 1986.

The $1.5 billion requested for space science and applications includes $25 million for initiation of US involvement with the Japanese and Europeans in the Global Geospace Science Mission.

This will use a series of spacecraft, beginning in 1992 and operating through the decade, to study the physics of Earth's magnetosphere and solar-terrestrial relationships.

Other items in the budget request include:

- $691 million for aeronautics and space technology, including continued work on the aerospace plane.
- $70 million to strengthen the nation's technology base and restore NASA's technical strength.
- $54 million for commercial programmes.
- $25 million for changes and upgrades to the Shuttle fleet.
- $20.6 million for construction of a Space Station Processing Facility and a Launch Complex 39 Operations Support Building at Kennedy Space Center.

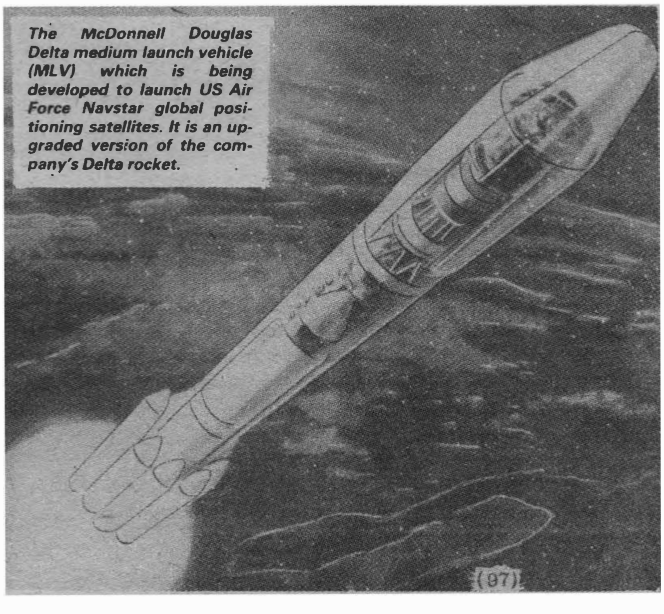
WEATHER SATELLITES SWITCHED

The National Oceanic and Atmospheric Administration (NOAA) is planning to switch the launch of its new geostationary and polar orbiting satellites from the Shuttle to expendable rockets.

Earlier agreements reached between NOAA and NASA (see 'World Weather Watch' p.113 of this issue) and the latest Shuttle manifest indicated that GOES I and NOAA K would be orbited by the Space Shuttle in 1993.

However, GOES I is now scheduled for an ELV launch in the second half of 1989 and NOAA K will be launched by an Atlas on a date that will depend on how long the two operational NOAA satellites continue to operate.

NOAA will also be procuring ELVs (Expendable Launch Vehicles) for the launch of four new GOES satellites planned for the 1990s.



The McDonnell Douglas Delta medium launch vehicle (MLV) which is being developed to launch US Air Force Navstar global positioning satellites. It is an upgraded version of the company's Delta rocket.

EUROPEAN RENDEZVOUS

Spot Image Builds Up Business

The French Spot satellite has acquired over 200,000 scenes of the Earth since its launch more than 12 months ago in February 1986.

Of these, around 48,000 are acceptable in terms of cloud cover and quality, with 11,000 depicting areas in Europe and the Middle East. Scenes so far processed to CCT (Computer Compatible Tape) and archived number around 5,000.

Production time required to process scenes to CCT is slower than originally anticipated. In fact technical problems and delays caused by management of orders and delivery procedures have resulted in some orders taking over six weeks instead of three to four as expected. Procedures are now in hand, however, to try and redress this situation.

Spot Image is now aiming for the following delivery schedules: 40 per cent of orders in two weeks; 35 per cent in two to four weeks; 15 per cent in four to six weeks; and 10 per cent taking longer than six weeks.

Spot Image, the company formed to market data from the satellite, reports that both radiometric and geometric quality are on average better than their original specifications. Problems include vertical striping on some occasions when the Multispectral and Panchromatic modes are cperated simultaneously and a CCD (charged coupled device) array fault which has the effect of creating four broad vertical bands in some images. Until these technical problems have been resolved Spot Image remains cautious about routine acquisition of simultaneous Multispectral and Panchromatic imagery.

Quick look production was unsuccessful all last year and Spot Image has now abandoned the system of production from videotapes. A new method has been introduced which will permit delivery of black and white "quick looks" to clients within two to three weeks. In addition, Spot Image is introducing a colour "quick look" facility of contact prints at 1:400,000 scale at a cost of about £20. These, however, will only be available for images of which colour films have already been produced.

So far 54 per cent of all sales have been generated in France, indicating a high level of government support for the new nationally developed technology. According to Nigel Press Associates, one of the authorised distributors for Spot data in the UK, the dominant market is the renewable resources sector.

The other UK agent, the National Remote Sensing Centre (NRSC) at Farnborough, recently reported that it had acquired 37 Spot scenes of the UK depicting 31 different areas, representing all the cloud-free imagery recorded by the satellite of the UK.

This coverage amounts to about 30 per cent of the land area. Of the 37 scenes only three are the high resolution panchromatic data.

Detail visible on the Spot data is very impressive. For example, with special enhancement, electricity pylons and even power lines have been detected on the multi-spectral data. At Heathrow airport aircraft on the runways and hard-standing are visible on the panchromatic data and sophisticated processing has even revealed the white line down the centre of the main runways.

The NRSC says some problems have been experienced obtaining colour imagery with good spectral differentiation and work is in progress to devise processing algorithms to maximise the information and prepare standard multi-spectral image products.

Further information about the availability of Spot images in the UK can be obtained from: Nigel Press Associates, Edenbridge, Kent TN8 6HS, or The NRSC, Space Dept., Royal Aircraft Establishment, Farnborough, Hants GU14 6TD.

WANTED: A movie (Reg 8 or Super 8) on John Glenn's orbital flight or the Mercury programme. Please send details to Mr. J-J Latapie, Place de la Mairie, Villelongue Par, 65260 Pierrefitte-Nestalas, France.

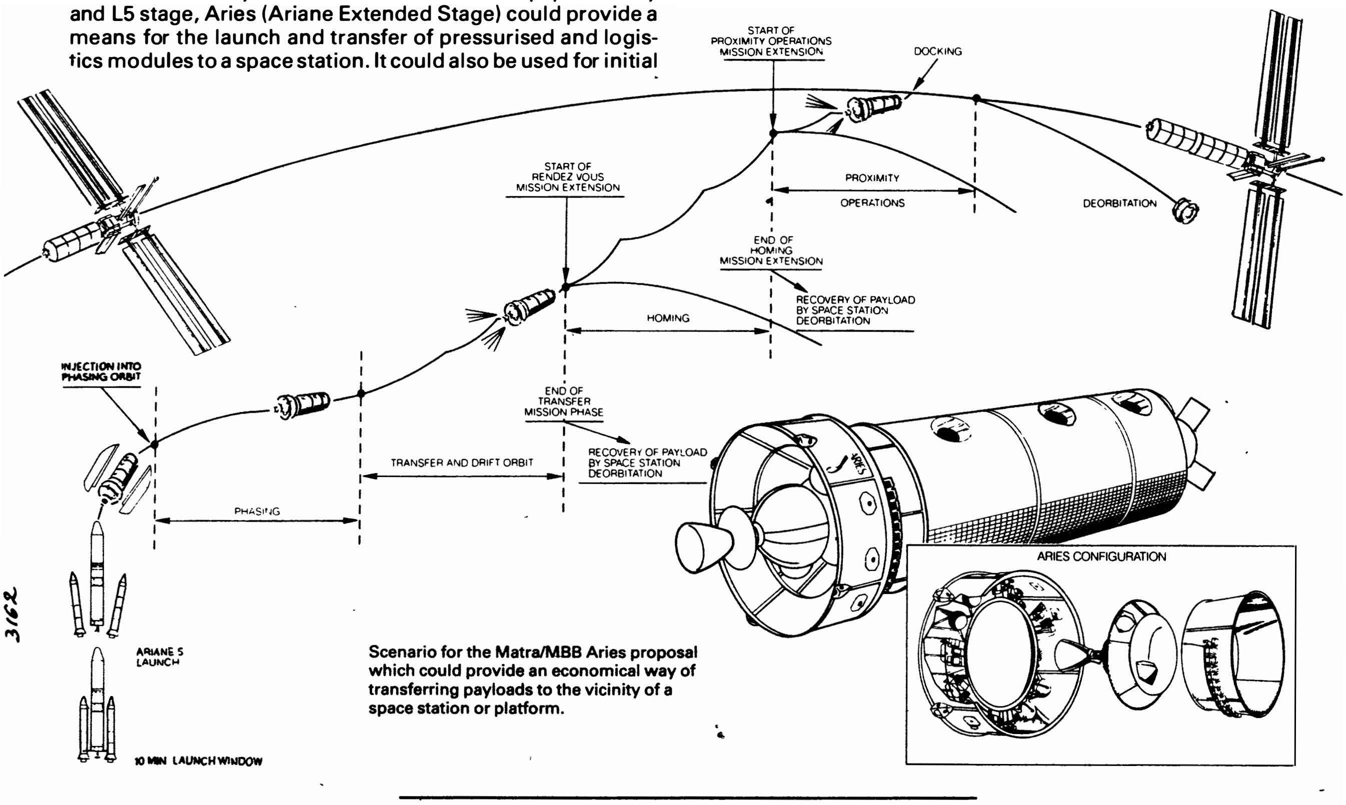
EUROPEAN RENDEZVOUS

Upper Stage Re-Use Proposal for Ariane 5

Aries, an expendable vehicle concept under study by Matra (France) and MBB-Erno (Germany) could provide Europe with a valuable extension to the operations of its Ariane launcher programme in the 1990's.

Derived directly from the Ariane 5 Vehicle Equipment Bay and L5 stage, Aries (Ariane Extended Stage) could provide a means for the launch and transfer of pressurised and logistics modules to a space station. It could also be used for initial assembly of an autonomous European station in Earth orbit.

Other possibilities include the launch and transfer of large payload modules towards a polar platform and rendezvous operations with a Space Station.



Scenario for the Matra/MBB Aries proposal which could provide an economical way of transferring payloads to the vicinity of a space station or platform.

HERMES – FIRST CONTRACTS

A plan to create, improve or restore to service some 15 European wind tunnels and other experimental facilities has been approved by ESA and the first contracts will be allocated to Switzerland (Swiss Federal Aircraft Factory, Emmen) and the Federal Republic of Germany (Stuttgart University).

The facilities are needed for in-depth aerodynamic studies on the design of the Hermes spaceplane. A wide flight envelope capability ranging from the hypersonic at atmospheric re-entry to the subsonic on landing will involve the use of a large number of wind tunnels and other experimental facilities.

Following the start of the Hermes preparatory programme at the end of last year, the European Space Agency (ESA) and the Centre National d'Etudes Spatiales (CNES) began to set up the industrial structure the Agency had approved at the end of November.

The first contract to be approved by ESA related to work for the prime contractor, Aérospatiale, and for Avions Marcel Dassault, the prime contractor for aeronautics. The tasks covered concern mainly study of the spaceplane configuration, with special reference to thorough analysis of crew safety aspects from launch until return-to-Earth.

Other contracts relating to the various spaceplane subsystems, the ground facilities needed for its development and operation and a large number of associated studies are in course of preparation. More than 250 industrial tenders are currently being evaluated.

MINISTER BACKS STATION

More than 300 potential Space Station users contributed to a recent utilisation study in the UK.

The Minister for Industry and Information Technology, Mr. Geoffrey Pattie, said this was an indication of the widespread support for activity in the UK.

Speaking at a recent Royal Society meeting, he described Space as "the new frontier" and said the UK should "organise for success".

"The importance of a manned Space Station lies in the powerful stimulus it will provide as a place where sustained research and development can be carried out in both science and technology," stated Mr. Pattie.

"UK participation in an international Space Station could be the key to continued scientific and industrial success," he added.

UK Projects for Mir Space Station

The Soviet Union has carried out space activities jointly with other countries, including Western countries, over a number of years. In the latter half of 1986 discussions took place and arrangements were put in hand for British participation. The start of a programme of Soviet-British space cooperation and its future possibilities are discussed here by Soviet physicist and mathematician *Tamara Breus.*

Initial Arrangements

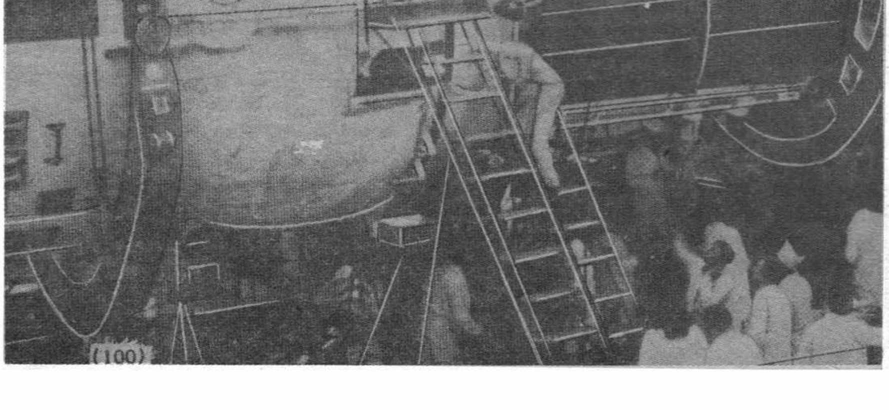
The possible scope of Soviet-British cooperation in space was discussed by delegations of the Intercosmos Council and the British National Space Centre (BNSC) in a meeting at the Institute of Space Research of the USSR Academy of Sciences which completed its work on October 1, 1986 [1]. The parties reached an agreement providing for Britain's participation in a Soviet programme of high-energy astrophysics for the early 1990s. Under the agreement, British scientists have undertaken to supply appropriate instruments for the experiments. Both sides expressed special interest in observations in the ultra-violet (UV) and X-ray regions of the spectrum.

The space research team at the University of Birmingham have now embarked on what may be seen as their first tentative step toward closer cooperation with the Soviet Union in space exploration. They have developed a series of instruments for the Roentgen Astrophysical Observatory, which will be docked with the Soviet Mir space station that was orbited in 1986. The Observatory will make observations in the X-ray region of the electromagnetic spectrum and, in terms of performance characteristics and scientific potential, will be unequalled this decade. An onboard Soviet telescope Pulsar-XI will carry detectors six times the area of the American HEAO-3 telescope detectors. The project also involves The Netherlands, West Germany and the European Space Agency.

Space Astronomy

X-ray observations offer the best opportunity to study the "hottest" and "most violent" features of the Universe. X-ray radiation originates in the "furnaces" of atomic and nuclear transformations which take place at temperatures approximating half a million degrees. In comparison, visible solar radiation emanates from a surface heated to a "mere" 5,500 degrees.

Experimental mock-up showing part of the Mir Space Station under going inspection by Soviet engineers. The station is primarily cosmonaut living quarters with science equipment and experiments being added in the form of separate modules.



The delegation of UK Parliamentarians, headed by Lord Whitelaw the Deputy Prime Minister, during their visit to Moscow in May 1986. Four months later Mr. Roy Gibson, Director-General of the BNSC, and Acamedician Roald Sagdeyev of the USSR signed an initial agreement (inset) for co-operation in space.

Young and hot stars, galactic gas and the pattern of gas in interstellar space, when studied in the UV region, are expected to provide information that will advance our understanding of the dynamical processes which lead to the formation of stars, protoplanet systems and protostar clouds.

British scientists have been invited to take part in discussions for a Soviet interferometer project, a giant radio system of synchronised surface-based and free-flying telescopes. With a resolution equivalent to that of a radio telescope with a 700,000 kilometre-wide dish, it will produce images of exquisite quality, thousands of times better than anything the biggest optical telescopes can produce.

The interferometer is designed chiefly to study the internal regions of the still mysterious quasars. A quasar is an exceptionally bright celestial object which emits copious quantities of radiation and is as bright as a whole galaxy of hundreds of billions of stars. Some scientists argue that the nearest quasar lies 15 billion light years from our planet, i.e. close to the limit of the Universe which can be studied by contemporary science. To study such objects would be to study the remote past.

Solar System Studies

No less exciting is the prospect of Soviet-British cooperation in the

physics of the Sun and the Earth and planetology. The Moscow meeting recommended the setting up of a special working group to discuss concrete aspects of cooperation in that field. British scientists welcomed the opportunity of taking part in the Phobos project as a first step in that direction [2].

This will be a unique project aimed at studying Mars and its natural satellites – Phobos and Deimos – using a remote laser mass-spectrometer. From a distance of a few dozens of metres the instrument will fire a pulse of laser light at the surface. The diameter of the laser spot will be about one millimetre and the density of energy will approximate 10 million watts. This laser will scatter ions and molecules from the surface in all directions. Some of these will reach detectors on board the spacecraft and yield information on the chemical composition of rocks that make up the soil of the satellite Phobos.

During the flyby the spacecraft will launch a long-lived, self-contained landing craft that will be equipped to explore the landing site. Another landing craft is designed to move across the satellite's surface.

To date 12 countries and the European Space Agency have volunteered assistance in the implementation of the Phobos project. The results of the experiment will be analysed on the basis of even broader cooperation.

Other Areas of Collaboration

Soviet and British delegates to the Moscow meeting agreed to discuss at some future date the possibility of expanding cooperation in space biology and medicine and materials technology. The Soviet Union has a record of orbital experience in excess of 100,000 hours in comparison with the US total of some 40,000 hours.

Space Technology

Another promising area of Soviet-British scientific cooperation could be space technology. The space technology age was inugurated in October 1969 when Soviet cosmonaut V. Kubasov staged the first series of experiments aboard the Salyut 6 orbital station and proved that technological operations in free fall are feasible.

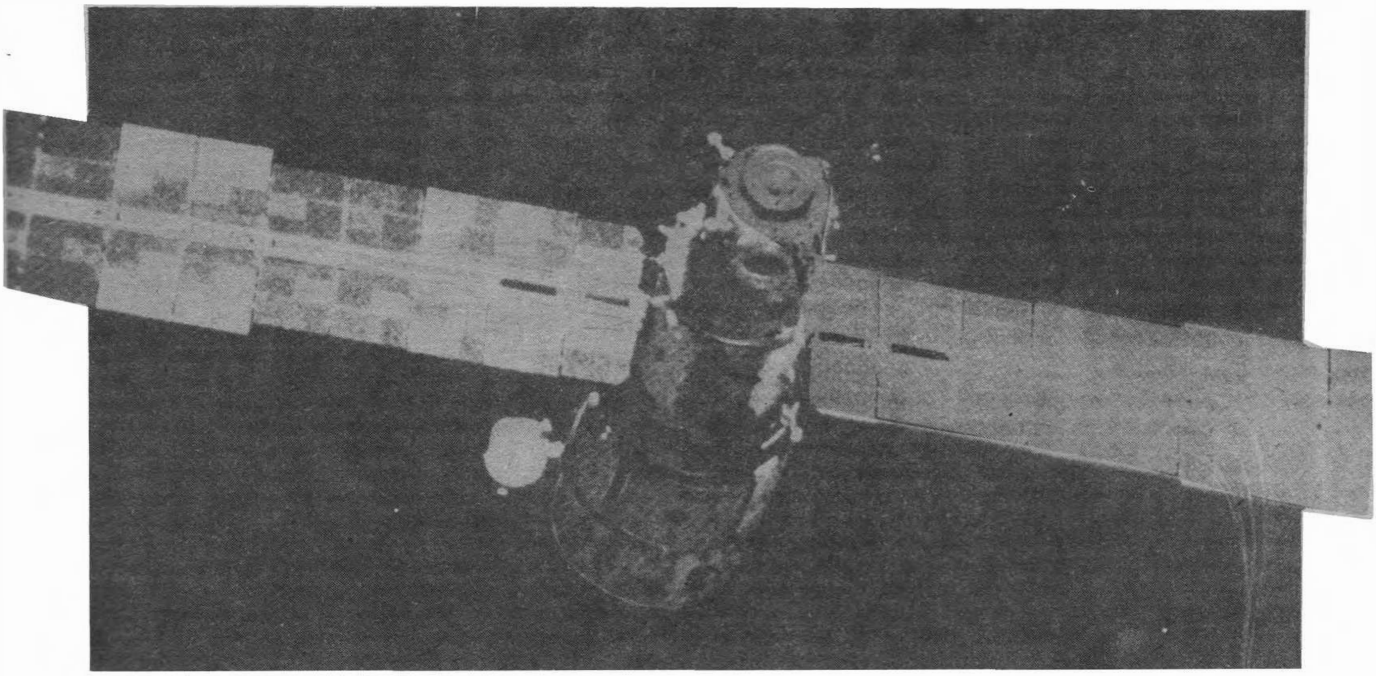
The first success gave rise to all sorts of tempting ideas, including the production of unique materials using the advantages offered by outer space. Ideas then gave way to experiments. Aboard the Salyut 6 station the crews carried out nearly 200 experiments in metal smelting and nearly as many in applying coats of gold, copper and certain alloys. They also produced close to 300 specimens of various metals. Some of them were later used in the prototypes of scientific instruments which, as a result, demonstrated a much better performance than instruments made of conventional metals.

Further progress in space technology is contingent upon advances in onboard technological equipment and, considering its increasingly sophisticated nature, it is essential that international cooperation in this area be upheld.

Soviet and British space research institutions are now actively probing the possibility of reaching agreements for a broader, fruitful cooperation between the two countries.

References
1. 'UK Soviet Space Deal', *Spaceflight*, vol 28, pp. 372-373 (1986)
2. 'UK Scientists to Join Phobos Mission', *Spaceflight*, vol 29, p.55 (1987).

View of the Mir Space Station in orbit as seen by cosmonauts Leonid Kizim and Vladimir Solovyov during their mission in 1986.



SOVIET SCENE

Spacemen at Mir

On February 7, 1987 the Soyuz TM-2 spacecraft docked at the Mir space station and cosmonauts Yuri Romanenko and Alexander Laveikin took up residence for an expected record-breaking stay in space. The docking manoeuvre followed a night-time launch two days earlier from Baikonur.

Compensations are offered by Mir to long-stay visitors in comparison with previous Salyut space stations in the form of improved living quarters. Small cubicles serve as "dormitories" for the crew and provide a degree of privacy not previously available. There is also a small dining area which features a hot plate for warming food. Exercise equipment is designed more compactly and purposefully.

The stationary bike is kept under the 'floor' and assembled for use and the running track has been relocated to allow the cosmonauts to look along the length of the station rather than at the walls, as on Salyut. The toilet is a small cubicle where the men can also wash their hands and face in a fountain of water whose outward flow is restricted by a transparent "hood" with three openings against which hands and face are placed.

The first tasks awaiting the newly arrived cosmonauts were to bring Mir into active service following its stand-down status since the departure from it of cosmonauts Leonid Kizim and Vladimir Solovyov on July 16, 1986. Essential services are provided by the station's life support system, temperature control system and the system for regeneration of atmospheric water. Already docked with Mir is the Progress 27 supply craft that was launched on January 18, 1987. This brought fuel supplies with which to refuel Mir's fuel tanks and a supply of food, drinking water and ancillary equipment.

Mir is approximately the same size as Salyut and the extra 'living quarters' have been provided in place of the large amount of scientific equipment carried internally by Salyut.

Mir will become operational as a 'work station' following the arrival and docking of the first large scientific module. Other modules are expected to dock with Mir at a later date and to remain attached to one of the four lateral ports that are a special feature of Mir. As the work-load on the cosmonauts increases their complement is likely to be increased as Mir is equipped to provide permanent living quarters for up to six cosmonauts, male and female.

The first scientific module is to be devoted to X-ray astronomy and will contain some 600-800 kg of instrumentation, including detectors from the UK (The University of Birmingham), The Netherlands, West Germany and ESA, as well as a Soviet telescope.

Mir provides a total of six possibilities for docking other vehicles, two axial and four lateral ports. After docking initially with one of the axial ports spacecraft will probably be moved to a lateral port using a manipulator arm.

It is not yet clear where the manipulator is located but it could be that modules will carry their own device for effecting transfers between docking ports.

The Soviets have also indicated that in the future a module could be added which would have a second docking unit for use by cargo craft.

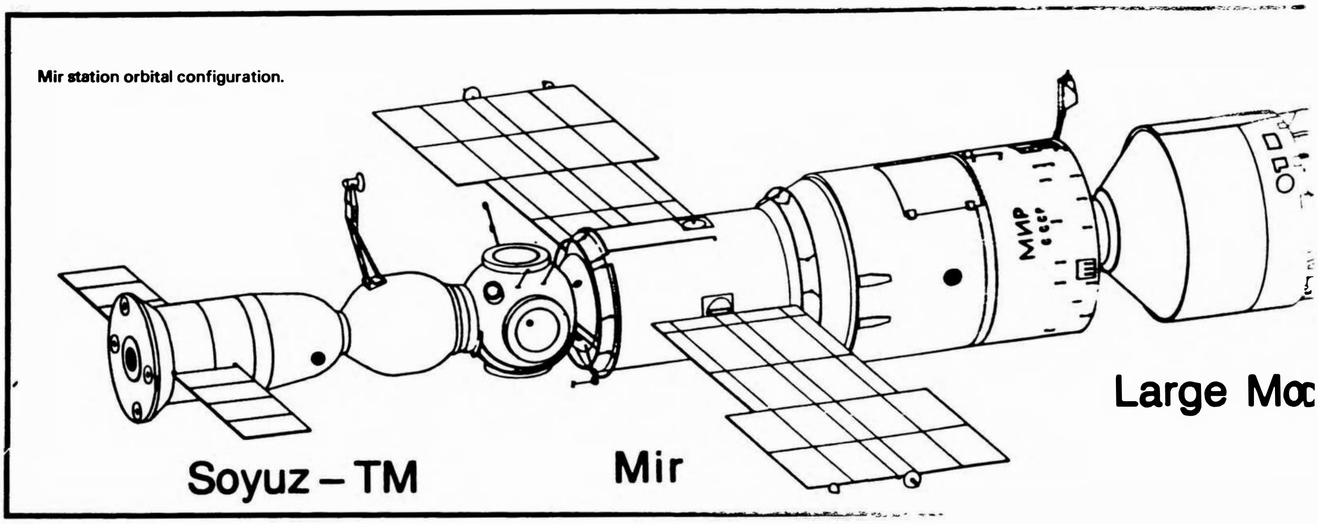
The Soviets have the capability to run a modest build-up programme over the coming months using a variety of vehicles. The initial operating configuration (see diagram on p.104) will consist of the Mir base, a large scientific module, the Soyuz-TM2 transporter and a Progress supply transporter.

The future Mir programme is also geared up for the arrival of foreign "guest" cosmonauts. These will include a Syrian, Frenchman and Bulgarian. The joint Soviet-Syrian mission has been scheduled to start on July 22, 1987 (*Spaceflight*, February 1987, p.56) whilst the other two will take place during 1988.

★ ★ ★

Mission commander Col. Yuri Romanenko and flight engineer Alexander Laveikin in a break during their splash-down training at sea prior to last month's lift-off from Baikonur. The two cosmonauts are not expected to return to Earth until the end of the year. It is common practice for the Soviets to return manned missions to a soft-landing on the ground. However, cosmonauts need to be familiar with techniques of landing at sea in case of emergency or a change of plans. *Novosti*


СССР
ОКЕАН



Mir station orbital configuration.

Mir – The First Permanent Space Station

With the launching of Mir on February 20, 1986 the USSR introduced its 'third generation' of space station. Previously, seven stations of the Salyut series had been orbited. Mir is different. Its central compartment is no longer a densely packed scientific laboratory, as in the case of Salyut, but is mainly a combination of wardroom and gymnasium. It also contains the station's control panel and computer and is not therefore entirely devoted to recreation.

Overall, Mir is 90 per cent different from Salyut in the way that it is equipped. One important difference is the inclusion of six, instead of two, ports for automatic docking of space ferries, manned and unmanned, and the attachment of specialised modules in which scientific and technical operations are to be conducted. Mir is therefore the basic component of a multipurpose permanently manned space laboratory which offers greater comforts for the crew than has been possible hitherto.

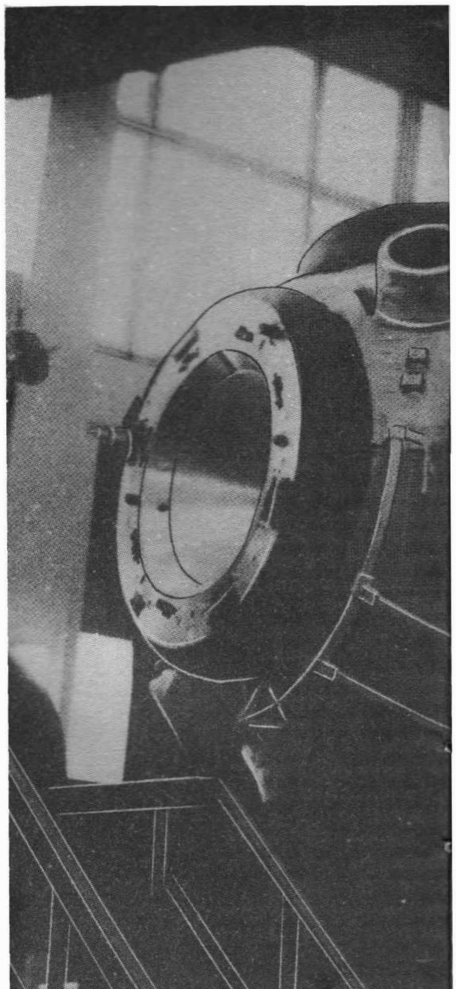
Mir's first crew were Leonid Kizim and Vladimir Solovyov who spent more than four months on board from March to July 1986. Among many new activities, they tested the system of communication to Earth via the 'Luch' communications satellite and made two spacewalks during which they tested a folding girder which is to be a structural element of future space constructions. They left Mir in a ready state to receive its next crew.

Previous to the re-opening of Mir, additional instruments and supplies (food, water and fuel) were delivered by the automatic unmanned spacecraft, Progress 27, launched on January 16, 1987.

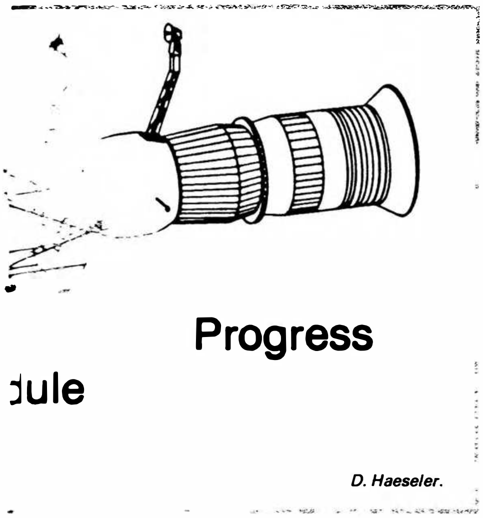
The new programme sees the introduction of the 'TM' series of Soyuz in its first use as a manned vehicle. On January 28, 1987 *Tass* announced the names of the crew members of Soyuz TM-2 to be Yuri Romanenko, mission commander, and Alexander Laveikin, flight engineer.

Romanenko has commanded two previous space flights. His Soyuz 26 mission to Salyut 6 began in December 1977 and was a record-breaking flight of 96 days duration. His second flight with Soyuz 38 in September 1980 was an international mission with a Cuban research cosmonaut and lasted 7 days. He is 42 years of age. Flight engineer Laveikin, on the other hand, has not participated in any previous space missions.

Soyuz TM-2 was successfully launched on February 5, 1987 from Tyuratam. The launch and the events leading up to it were the subject of public announcements and TV coverage, showing a significant relaxation on the part of the Soviet authorities.



A recently released picture of Mir orbital station while installed at its checkout facility where it was fitted out with an entirely new docking unit of six docking ports. The station contains many improvements, such as a more effective power supply system, and it offers greater crew facilities.

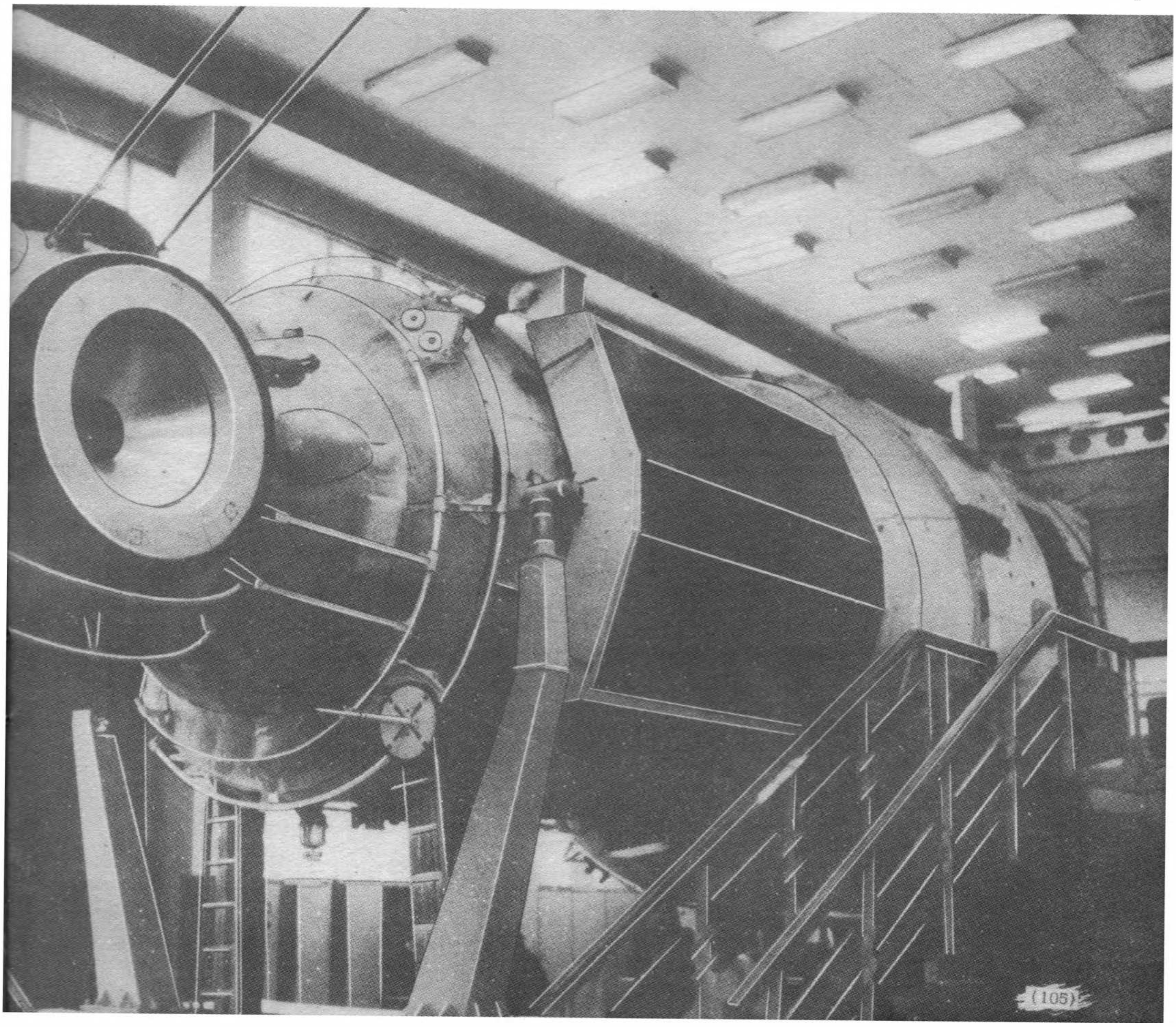


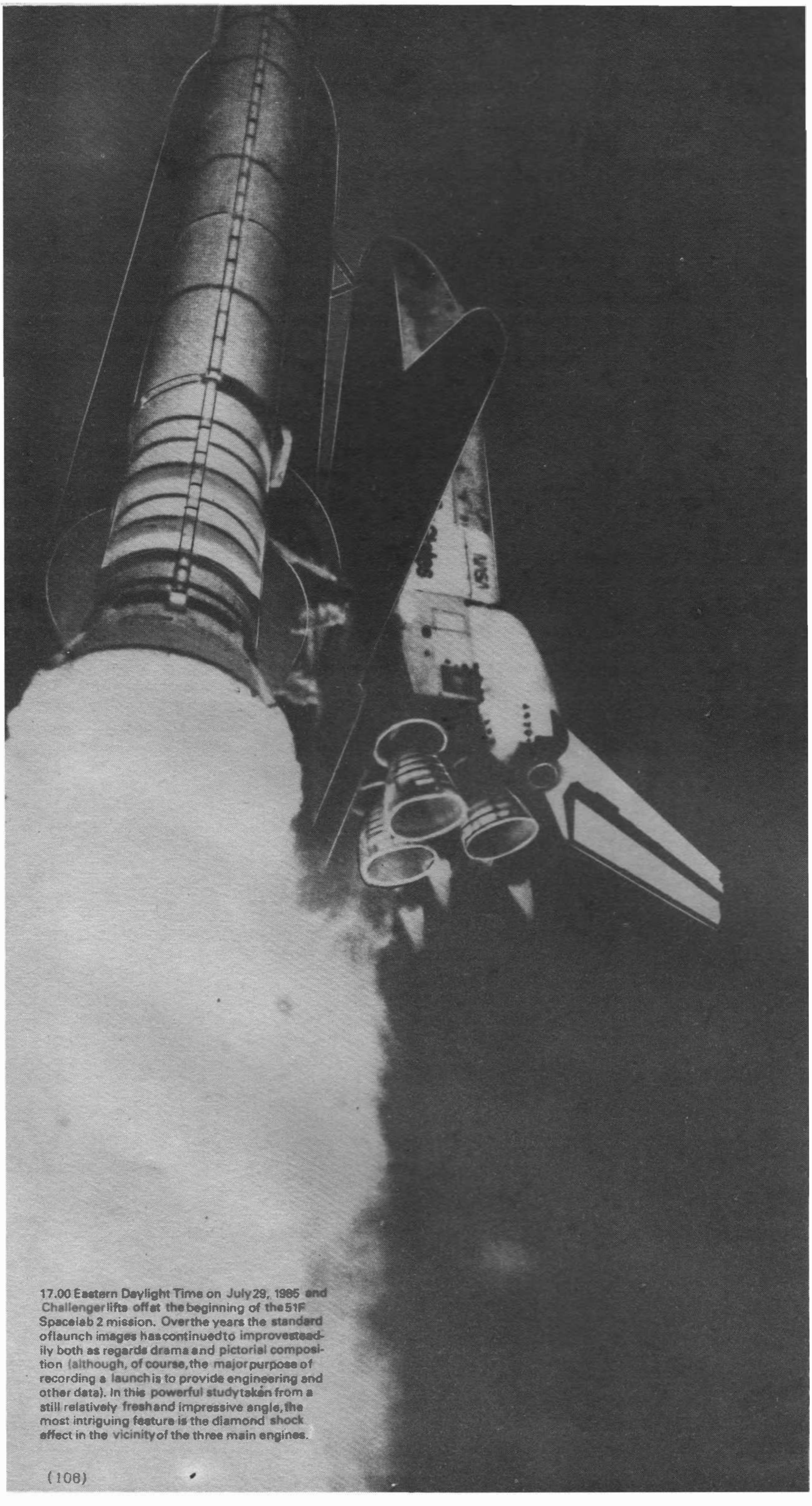
D. Haeseler.

Yuri Romanenko.

Alexander Laveikin.

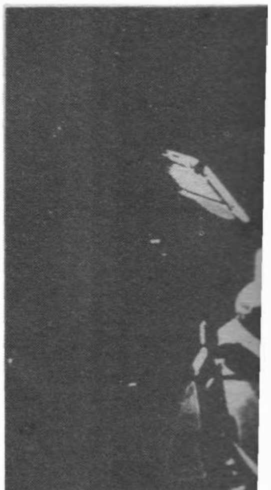
Novosti





17.00 Eastern Daylight Time on July 29, 1985 and Challenger lifts offat the beginning of the 51F Spacelab 2 mission. Overthe years the standard oflaunch images hascontinuedto improvesteadily both as regards drama and pictorial composition (although, of course, the major purpose of recording a launch is to provide engineering and other data). In this powerful study taken from a still relatively fresh and impressive angle, the most intriguing feature is the diamond shock effect in the vicinity of the three main engines.

**In February 1984 NASA carried out t
(MMU). Some fine, much closer and
obtained during this 41B mission of C
facing astronaut Bruce McCandless
from the orbiter.**



Douglas Arnold presents a personal choice of . . .

IMAGES FROM SPACE

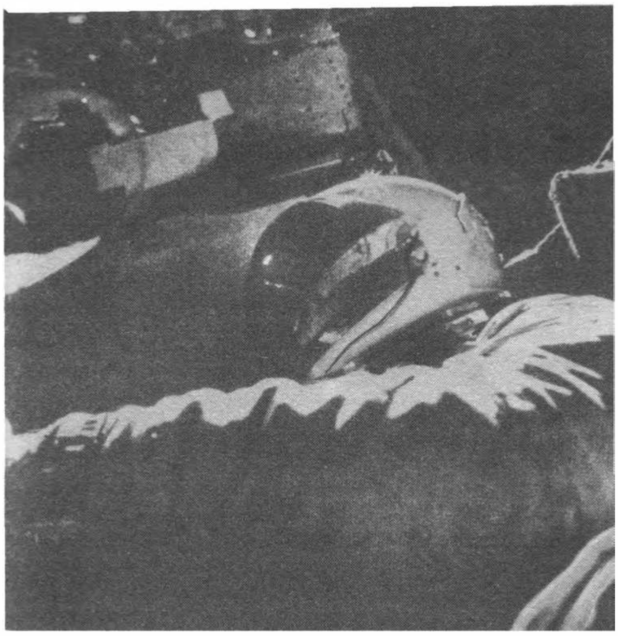
...rst untethered EVA using the Manned Manoeuvring Unit ...fore more detailed images of the EVA astronauts were ...nger but this one suggests perhaps best of all the danger reached his maximum permitted distance some 300 feet

Pictures have documented the progress of space flight throughout its relatively short history. Many of these images, however, have not only produced information – some have captured moments of drama, beauty or "atmosphere" that have helped to communicate the space experience.

Other images have assumed abstract forms that bridge the apparent gap between scientists and artists – a gap which, in fact, has never really existed because, for many years, artists have journeyed in their imaginations far beyond Earth – challenging and inspiring engineers and technologists to turn dreams into reality.

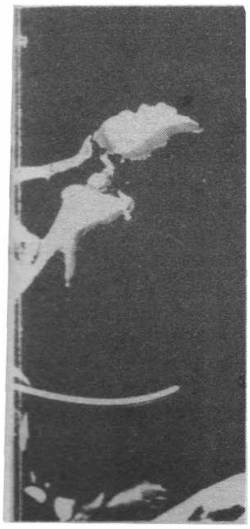
The 'Images of Reality' appearing on these pages have been selected to convey an exotic reality that is characteristic of the space environment.

In contrast, the use of false colour enhancement and other techniques intended to extract maximum information can create abstract forms. Such possibilities abound on Mars which presents the lively imagination with a new world to explore (see pages 130 and 131).



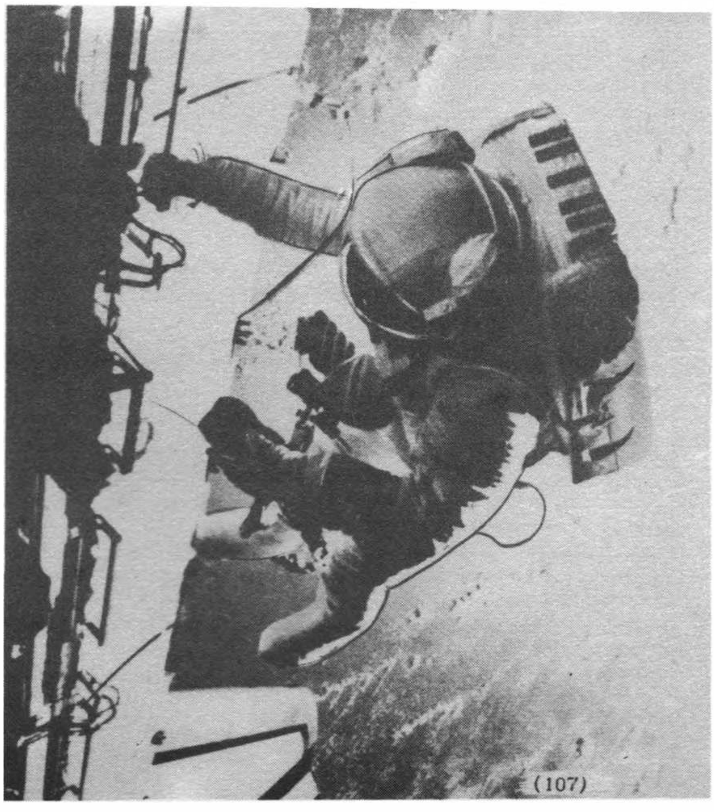
One of the most dramatic of in-cabin photographs ever – during the Gemini XI mission in September 1966 mission commander Charles 'Pete' Conrad captured this image (above) of colleague Richard Gordon fully space suited during an equipment dump. The hatch is open and the stark blackness of space appears at top right. The lighting is typical of the contrasting conditions which exist in space where there is no atmosphere and often no other objects to scatter or reflect the Sun's brilliant rays as on Earth.

Pictures· *Space Frontiers/NASA*



During the flight of Apollo 7 – the first and least publicised of manned Apollo missions – some fine photographs were obtained and none better than this portrait (left) of astronaut Walter Cunningham whose face appears in profile sharply etched by sunlight. A command module window is behind him and intercom cables appear beneath his chin. His face shows signs of the strain and fatigue of a lengthy mission in space. The Apollo 7 flight took place in October 1968.

In November 1984 Shuttle astronauts conducted EVAs to retrieve two communications satellites which had not gone into their correct orbits. In this image astronaut Dale Gardner – safely tethered to the side of the cargo bay of Discovery – prepares for the hard work that was to follow. We are given a fine impression of the Earth's oceans below as the vehicle orbits at a speed of approximately 18,000 mph



BOOK NOTICES

Origin of the Moon

Eds. W.K. Hartmann *et al.* Lunar & Planetary Institute, 3303 Nasa Road 1, Houston, Texas 77058-4399, USA. 781pp. 1986, $25.

When the decision was made to explore the Moon and bring back lunar samples scientists hoped that the resulting information would clarify its origin. Indeed, solving this particular mystery was accepted as a major goal of lunar exploration.

It had been expected that the chemistry of primordial lunar rocks would clarify the formative processes so astronauts were trained to identify such 4.5 billion year old specimens. Unfortunately, if they existed, such specimens were not to be found above the layer of powdery dust that blankets virtually the whole of the lunar surface including the Apollo landing sites.

As the problem now stands there are three basic suggestions: that the Moon could have been formed by capture, fission or accretion.

This volume attempts to bring all the threads together, beginning first with two papers which provide overviews of the problems of lunar formation, followed by three sections which deal with the dynamical, geochemical and geophysical constraints respectively.

The main bulk of the book continues with 15 papers on possible theories to explain the Moon's origin and evolution. Few follow the usual pattern by re-stating previous material: indeed, the aim was to encourage 'new thinking', as evidenced by papers such as those which postulate a scenario involving a circumterrestrial disc of small bodies which formed into the Moon by a process of accretion. The other end of the scale includes a paper based on the hypothesis that the Moon formed separately in a heliocentric orbit, in similar manner to the Earth, and was later captured. Actually, a capture-origin that employs a 'push-pull' tidal theory does not strain the laws of physics too much and involves a minimum of assumptions.

This volume is up to the standard that one always associates with the publishers and provides valuable perspectives of a most intriguing problem.

Black Holes: The Membrane Paradigm

Eds. K.S. Thorne *et al* Yale University Press, 13 Bedford Square, London WC1B 3JF. 1986, 367pp, hardcover, £37.50.

This book is a pedagogical introduction to the physics of black holes but with emphasis on the viewpoint 'membrane paradigm'. This is really a translation of mathematical and physical formalism for black holes into a form specifically adapted to astrophysical research. Whereas the original black hole formalism was understandable only to those well versed in the theory of general relativity, the membrane paradigm is accessible to a much wider circle, and probably to all with a good grounding in non-relativistic physics.

The physical intuition so central to the membrane paradigm can be built up only by watching it 'in action' in a variety of contexts. This book provides such an insight by posing, solving and discussing a large number of model problems in which black holes interract with the external universe.

Although the result of collaborative effort this book is not simply a collection of closely-related papers. Rather, the chapters provide a coherent, closely-knit whole.

Cosmic Magnetism

P. Seymour, Adam Hilger, Techno House, Redcliffe Way, Bristol, BS1 6NX. 150 pp, 1986, £14.95.

The study of extraterrestrial magnetic fields is relatively new, for confirmation of the very first discovery (that of our Sun), appeared only as recently as 1908. Since then a good deal of knowledge has accumulated to show that this is a fascinating subject worthy of much detailed study.

This book is probably the first which deals with the topic in a non-mathematical way. Its opening three chapters summarise our present knowledge of magnetism in general, the magnetic field of the Earth and the reasons which led to the study in Cosmic Magnetism in particular. The remainder of the volume turns on the main topic – solar, planetary and interplanetary fields, fields in stars and pulsars, and in the Milky Way and other galaxies.

Photochemistry of the Atmosphere of Mars and Venus

V.A. Krasnopolsky, Springer-Verlag, Heidelberger Platz 3, Postfach, D-1000 Berlin 33, West Germany. 1986, pp 334.

Our present knowledge of the properties and conditions of the planets exceeds many-fold that of 20 years ago. This is especially true for planetary atmospheres whose properties were then, for the most part, either not known at all or subject to many errors.

This book, vol. 13 in the series with the general title of 'Physics and Chemistry in Space' provides a fully detailed description of the chemical composition and structure of the atmospheres of Mars and Venus, together with the processes which govern the properties of these atmospheres.

Although the topic may seem, at first glance, to be far removed from the needs of humanity, it is of considerable value insofar as human activity is already influencing the Earths' environment, e.g. with atmospheric pollution, and it is important to understand its resilience to such factors.

The book compiles the experimental and theoretical data collected over the last decade from ground-based observations as well as by Soviet and American probes, orbiters and descent probes. Various methods for determining the chemical composition of planetary atmospheres are reviewed and the reliability of experimental results compared with predictions based on photochemical modelling, critically discussed.

Relativity in Celestial Mechanics and Astrometry

Eds. J. Kovalevksy & V.A. Brumberg. D. Reidel Publishing Co., Spuiboulevard 50, P.O.Box 989, 3300 AZ Dordrecht, The Netherlands. 1986, 426pp, £44.50.

This book presents the proceedings of the first-ever international conference to involve, simultaneously, theoreticians in general relativity on the one hand and astronomers, space scientists and geodecists (i.e. the "users" of the theories) on the other.

In recent years accuracy in determining positions of celestial bodies has greatly improved, along with developments in the theory of their motions. Parallel to this, interpretation of astrometric and space measurements within the framework of general relativity has also greatly improved.

This volume deals with the latest results in all these fields. Its contributions include such topics as dynamical effects in general relativity, accurate modern theories of motion within the Solar System, time, relativistic reduction of astronomical observations, among many others. Additionally, plans for future high-precision observational techniques are presented, along with a few papers on relativity which extend beyond the current limitations of accuracy.

The Study of Variable Stars Using Small Telescopes

Ed. J.R. Percy, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1986, 265 pp, £20.

Variable stars are stars that change in brightness. They are important in astronomy not only because they are so numerous but because they can provide valuable information about the structure and evolution of stars generally. Even though large sophisticated telescopes are used to study variable stars, small telescopes, too, have an important role to play.

Areas in which the amateur can make useful contributions are discussed in several papers in this volume. More exceptionally, the amateur might discover a nova or make useful observations of such objects during phases of expansion or decline. Ambitious programmes could include large-scale surveys of variable stars, e.g. spectral classification, radial velocities or intensive and complete phase coverage of regular short-period phenomena.

This book comprises 23 short papers presented at a Symposium held at the University of Toronto in 1985 aimed at professional and amateur astronomers alike, including astronomy teachers at universities possessing small telescopes.

The techniques of visual, photographic and photoelectric measurements are discussed, with examples of the results obtainable. Infrared and spectroscopic techniques are also examined and important related topics such as periodic analysis, coordination and the archiving of data are included.

The Quest for SS433

D.H. Clarke, Adam Hilger, Techno House, Redcliffe Way, Bristol, BS1 6NX. 206pp, 1986, £9.95.

Luck, fate and coincidence played a major role in June 1978 with the discovery of the unusual properties of SS433, a supernova remnant now regarded as one of the astronomical enigmas of this century.

Observations throughout the 1970's had indicated strange patterns of radio and X-rays coming from a general area, apparently from an object which not only appeared to be approaching but also receding at the same time and which was emitting jets of material at speeds never before witnessed in the galaxy. These were matters that defied explanation by any of the then current theories about the composition of the Universe and this compelled astrophysicists to modify their ideas of stellar evolution.

In this book one of the co-discoverers recounts the event leading to pinpointing this strange object and discusses some of the mysteries surrounding it, though all the problems posed by SS433 have still not been resolved. For example, will its status be only short lived, as for so many celebrities, or will it remain a truly unique object of basic importance to astrophysics? This book, in the manner of a detective story, provides the reader with lots of clues and some ideas about where the final explanation may be found.

Halley the Beautiful

Slide set from The Planetarium, College Hill, Armagh, Northern Ireland. 1986, £11.00.

Even though Halley's Comet was a disappointing naked-eye object in the Northern Hemisphere, many fine pictures were taken.

This set of 30 slides, together with a coloured brochure, recaptures some of the best secured during the 1985/6 apparition and represents not only an excellent souvenir of the occasion but a source of illustrative material suitable for use in astronomical and space lectures.

Artificial Intelligence for Space Station Automation

O. Firschein et al. Noyes Publications, Mill Road at Grand Avenue, Park Ridge, NJ 07656, U.S.A. 1986. 386pp. $48.

Applications of artificial intelligence to space station automation are certain to yield enormous advantages in crew safety and productivity. They will also increase the R&D projects descibed in this book and will undoubtedly accomplish these objectives. Many of them also have application to terrestrial automation.

The book provides guidance on the state-of-the-art of AI-based technologies and reveiws the results of concept design studies to determine AI capabilities. Some of the specific technologies deal with teleoperation and robotics, sensors, expert systems, computers, planning and the man-machine interface.

The book was prepared by a galaxy of authors with support from the NASA Advanced Technology Advisory Committee at Johnson Space Center. The challenge of space station automation will inspire further advances in AI-based technology and provide vital industrial skills for the future.

Annual Review of Astronomy and Astrophysics Vol. 24, 1986

Eds. Burbidge, Layzer & Phillips. Annual Reviews Inc., 4139 El Camino Way, Palo Alto, Ca. 94306, USA. 1986, 627pp. $47.

This further compilation of review articles concentrates heavily on astrophysics with a selection of 16 papers providing overviews on matters ranging from the physics of supernova explosions to star counts and gallactic structure.

The number of papers is a little smaller than in previous years but still provides excellent reading matter about the frontiers in astrophysics today.

Methods of Satellite Oceanography

R.H. Steward, University of California Press, London. 1986, 360pp, £32.75.

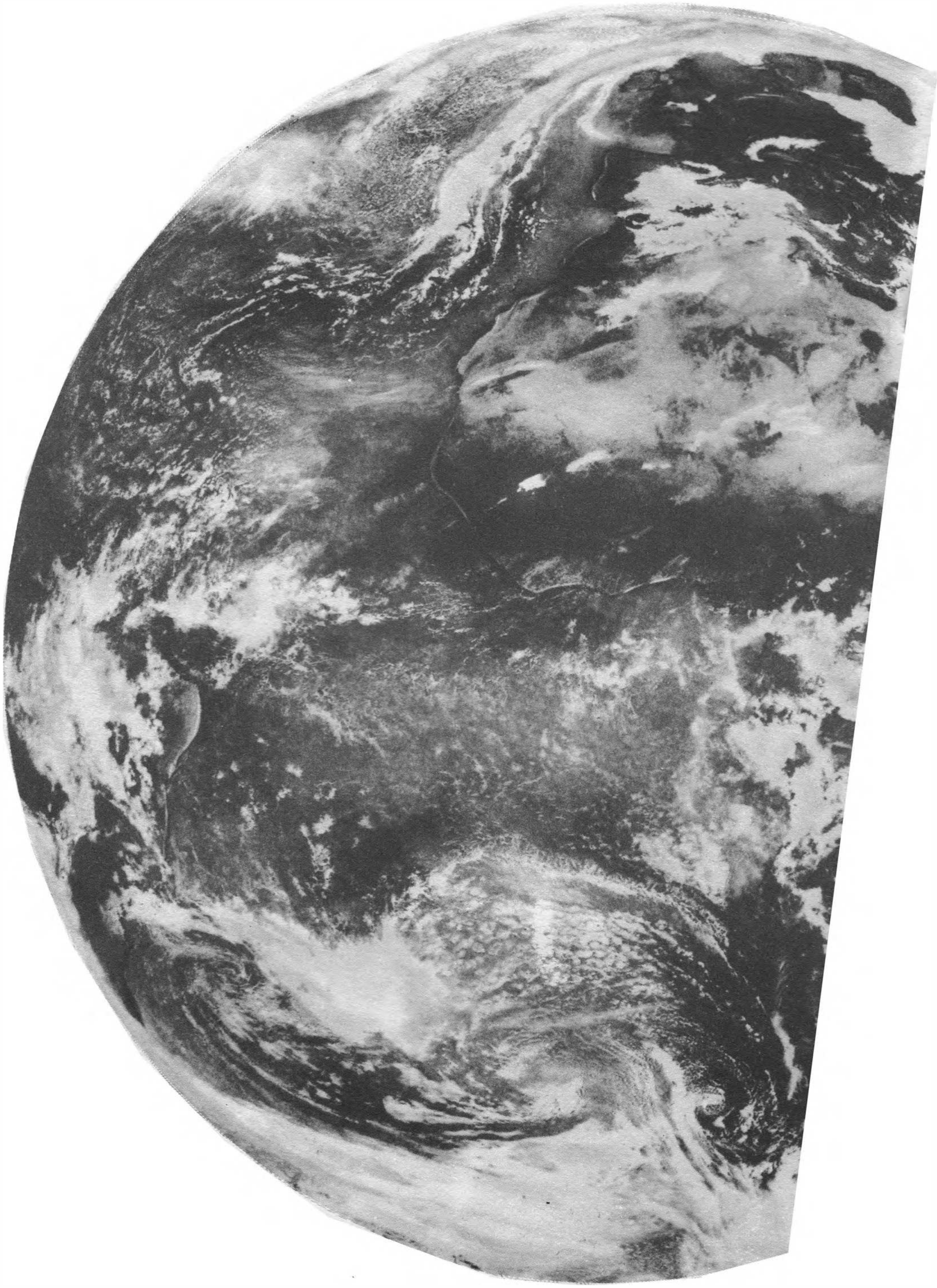
For centuries oceanographers depended on sparce measurements from a few ships slowly making their way through uncertain seas. Today, with the deployment of ocean observing satellites, a total coverage of the world's oceans can now be achieved in just a few days. Satellite remote sensing not only enables oceanographers to observe regions not easily studied by ships but makes it possible to obtain a global picture of the oceans for studies of phenomena especially important in our understanding of climate and ocean dynamics.

Dramatic advances in remote-sensing techniques have proved that the application of data acquired from satellites will strongly influence oceanography in the years to come but until now, however, most developments in remote-sensing techniques have taken place outside the traditional oceanographic community and been largely based on the ideas and instruments first used by astronomers, planetologists, radio scientists and meteorologists.

This book brings together a wealth of information on remote sensing hitherto widely scattered in the literature or poorly documented because of rapid expansion of the field.

The author describes the principles of the interaction of electromagnetic radiation in the Earth's atmosphere with the oceans over a range of frequencies, the techniques for exploiting these interactions to study the oceans and the type of instruments and satellites now available together with accuracy and usefulness of the measurements thus obtained.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.



WORLD WEATHER WATCH

A Meteosat view of the Earth. The image, taken a 11.55 GMT on March 26, 1982, is artificially coloured in the visible channel and was received and processed at ESOC Darmstadt. *ESA*

by Joel Powell

For the past quarter of a century meteorological satellites have maintained a silent vigil of the Earth's weather from space. Satellites in geostationary orbit and lower polar orbit are a valuable complement to the traditional ground-based methods of weather forecasting.

Meteorological Satellites

Before the advent of the Space Age, scientists recognised that space would provide an ideal vantage point for observing the Earth's weather. Beginning with Tiros 1 in 1960, weather satellites have been designed to acquire planet-wide images of cloud cover and to measure atmospheric conditions with increasingly sophisticated remote sensing instruments.

Studies have shown that the contribution from satellite measurements to computerised forecasts is greatest for the vast ocean regions, especially when oceanic weather affects the continents. Satellite data has the greatest impact on weather forecasts for the Southern Hemisphere but comparatively little influence for the Northern Hemisphere, with its greater degree of surface coverage.

One of the more noteworthy functions of 'metsats' is the detection and tracking of hurricanes and typhoons. Before weather satellites, these severe storms would often strike tropical islands and coastal areas without warning, resulting in tremendous loss of life and property damage. Today, storm warnings provided from space allow authorities to evacuate and prepare population centres well in advance.

The United States' network of weather satellites is operated by the National Oceanic and Atmospheric Administration (NOAA), a branch of the Commerce Department of the government. The largest user of satellite weather information is the US National Weather Service, supplementing its extensive balloon, surface and sophisticated weather radar observations.

At the NOAA facility in Suitland, Maryland, weather

GMS, the Japanese weather satellite operating in geostationary orbit.

satellite images are processed and atmospheric data fed into the forecasting computers of the National Earth Satellite Service. Cloud pictures and weather maps are distributed to users around the world *via* the Weather Facsimile (WEFAX) system, using dedicated relay transponders on the geostationary weather satellites.

Images can be obtained directly from the polar orbiters using an inexpensive radio receiver and a facsimile machine, which can also be used with WEFAX. Known as Automatic Picture Transmission (APT), the service was first introduced on Tiros 8 in 1963.

Polar Orbiters

All American low altitude and polar weather satellites have been built by RCA Astro-Electronics The latest model is the 4.9 m long Advanced Tiros-N (ATN) spacecraft that weighs 1,030 kg in orbit.| The three-axis stabilised vehicles are derived from the US Air Force's Defense Meteorological Satellite Program, a separate network of military weather satellites.

Table 1. Weather Satellite Genealogy.

Polar Orbit	Geostationary Orbit
Tiros: 1960-65	Applications Technology Satellite (ATS, for R & D): 1966-74
Nimbus: 1964-78 (R & D)	Synchronous Meteorology Satellite (SMS): 1974-78
ESSA: 1966-69	GOES: 1980 to date
ITOS (Tiros-M): 1970-76	
Tiros-N: 1978-81	
Advanced Tiros-N: 1983 to date	

The NOAA craft operate from two Sun-synchronous polar orbits (known as 'morning' and 'afternoon', indicating local time of equator crossing).The spacecraft in the morning orbit, NOAA-8, orbits at an altitude of exactly 833 km and is inclined 98.7 degress to the equator. Equatorial crossings occur at 07.30 local time. The present occupant of the afternoon orbit, NOAA-9, operates at an altitude of 870 km and is inclined 98.9 degrees to the equator. The equator crossing time has recently been adjusted from 1500 to about 1400 local time to allow earlier forecasts. Thanks to the Earth's rotation, a satellite travelling in a 100 minute polar orbit is able to pass over the entire Earth's surface twice every day.

The daylight imaging system of Tiros-N/ATN, designated as the Advanced Very High Resolution Radiometer (AVHRR), produces images in visible and infrared light with a resolution of 0.9 km and 3.7 km, respectively. Each image encompasses an area of more than 10 million km².

A separate trio of instruments known as the Tiros Operational Vertical Sounder (TOVS) is used to perform atmospheric soundings. The first instrument is HIRS/2, the High Resolution Infrared Radiation Sounder. This infrared radiometer is used to measure temperatures in the stratosphere and troposphere, as well as water vapour content and the concentration of atmospheric ozone.

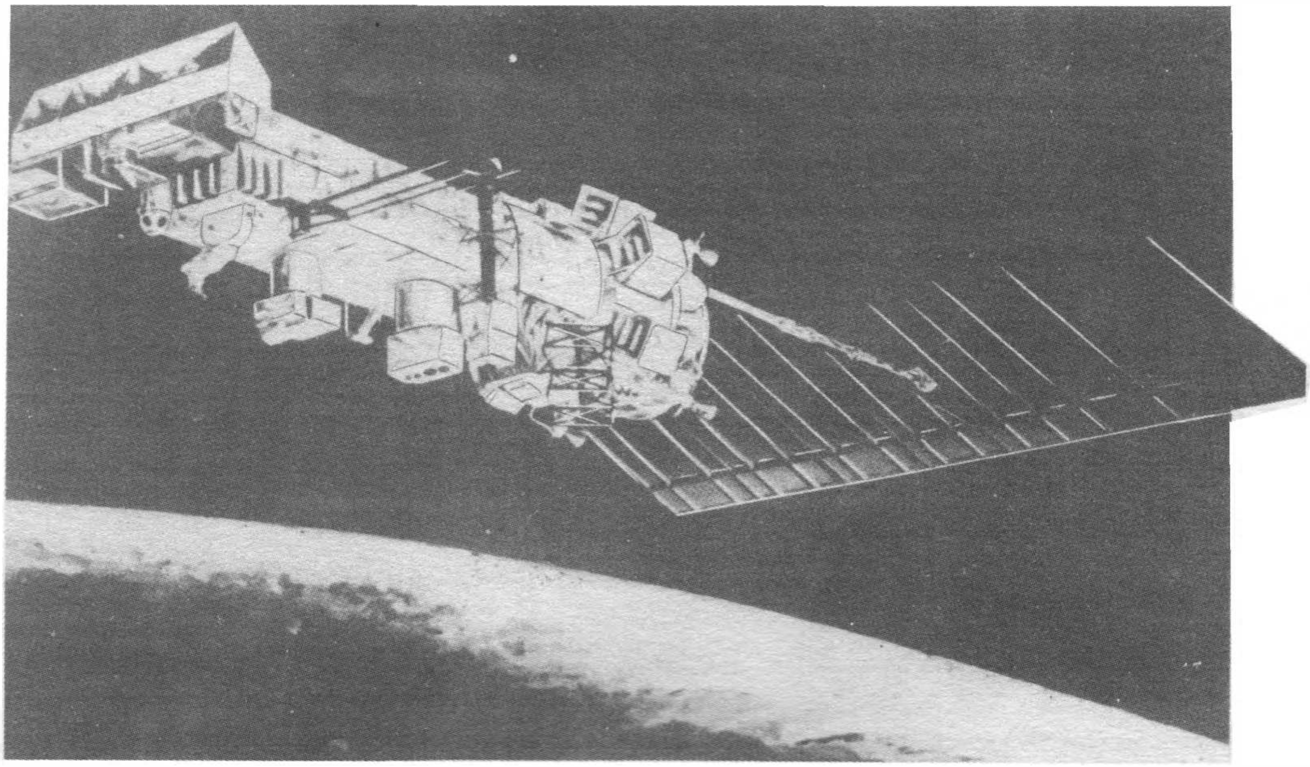
The second TOVS sensor is the UK's contribution to satellite meteorology, the Stratospheric Sounding Unit. SSU determines vertical profiles of temperature and pressure in the stratosphere by means of infrared spectroscopy. Completing the trio is the Microwave Sounding Unit (MSU). This four-channel radiometer takes temperature and other measurements in the oxygen emission band which, unlike the other sensors, is relatively unaffected by cloud cover.

Although atmospheric soundings constitute the only data available from many remote areas, the readings are subject to limitations compared to conventional methods. Satellite temperature measurements are up to four times less accurate than those from balloon sondes, which are in error by less than ± 0.5 degrees C. Determining the altitude component of satellite soundings is also a problem. The value of wind and pressure readings used in computer-generated forecasts is diminished without a precise altitude correlation.

TOVS is also capable of measuring sea surface temperatures to help the charting of currents for the benefit of fishermen and mariners. Wind speed measurements derived from TOVS data are used by airlines to plot the most fuel-efficient courses.

The ATN spacecraft features the unique capability to receive distress signals from 121.5 MHz emergency transmitters on ships and aircraft. SARSAT (Search and Rescue Satellite-Aided Tracking) is a multinational programme of Canada, the United States, France and the Soviet Union. The Soviet COSPAS search and rescue hardware is carried aboard Cicada navigation satellites and is fully compatible with its Western counterpart.

The Soviets and Americans have each agreed to maintain two SARSAT-equipped satellites in orbit at all times. SARSAT/COSPAS is credited with saving nearly 400 lives in the first three years of operation.



The advanced Tiros-N polar orbiting weather satellite with boom-mounted SARSAT antenna in foreground. *RCA*

Each NOAA polar orbiter also carries ARGOS, a French-built data collection system designed to relay signals from a global network of remote environmental sensors. Stationary and balloon-borne instruments register atmospheric pressure, temperature and rainfall, while buoys monitor water levels to warn of floods and tsunamis. Both the American and European geostationary satellites have a similar system that relays signals from several thousand remote platforms.

Although an attempt by the Reagan administration to sell the polar orbiting network to private industry failed in 1982, a controversial plan to limit the system to a single operational satellite was recently implemented. There will be no replacement when one of the present two polar orbiters fail, and future NOAA spacecraft will not be launched until the remaining vehicle shows signs of deterioration. The policy is expected to result in a saving of at least $300 million over ten years, but at a cost of half the data currently available.

In late 1984 a dispute arose between NOAA and NASA over the launch vehicle to be used for the final three ATN spacecraft (NOAA-K,L & M). NASA had planned to orbit the three satellites from California aboard the Space Shuttle, but for economic reasons NOAA decided that refurbished Air Force Titan II boosters would be used instead.

The conflict was eventually resolved when NOAA agreed to deploy the three weather satellites with the Shuttle if NASA would absorb the costs of modification for such launch. In addition, NOAA agreed to commit its 'NOAA-Next' package of advanced weather instruments to the man-tended polar orbiting platform that will be part of NASA's Space Station Programme in the 1990's.

Geostationary Satellites

Geostationary satellites are the newest addition to the space meteorology system, first appearing in 1974. Orbiting at an altitude of 35,880 km, craft in such an orbit appear to hover in a fixed position directly above the equator. This is because the motion of a satellite at that altitude exactly matches the rotational speed of the Earth. A minimum of three satellites at this altitude are required to keep all of the Earth's surface in view simultaneously.

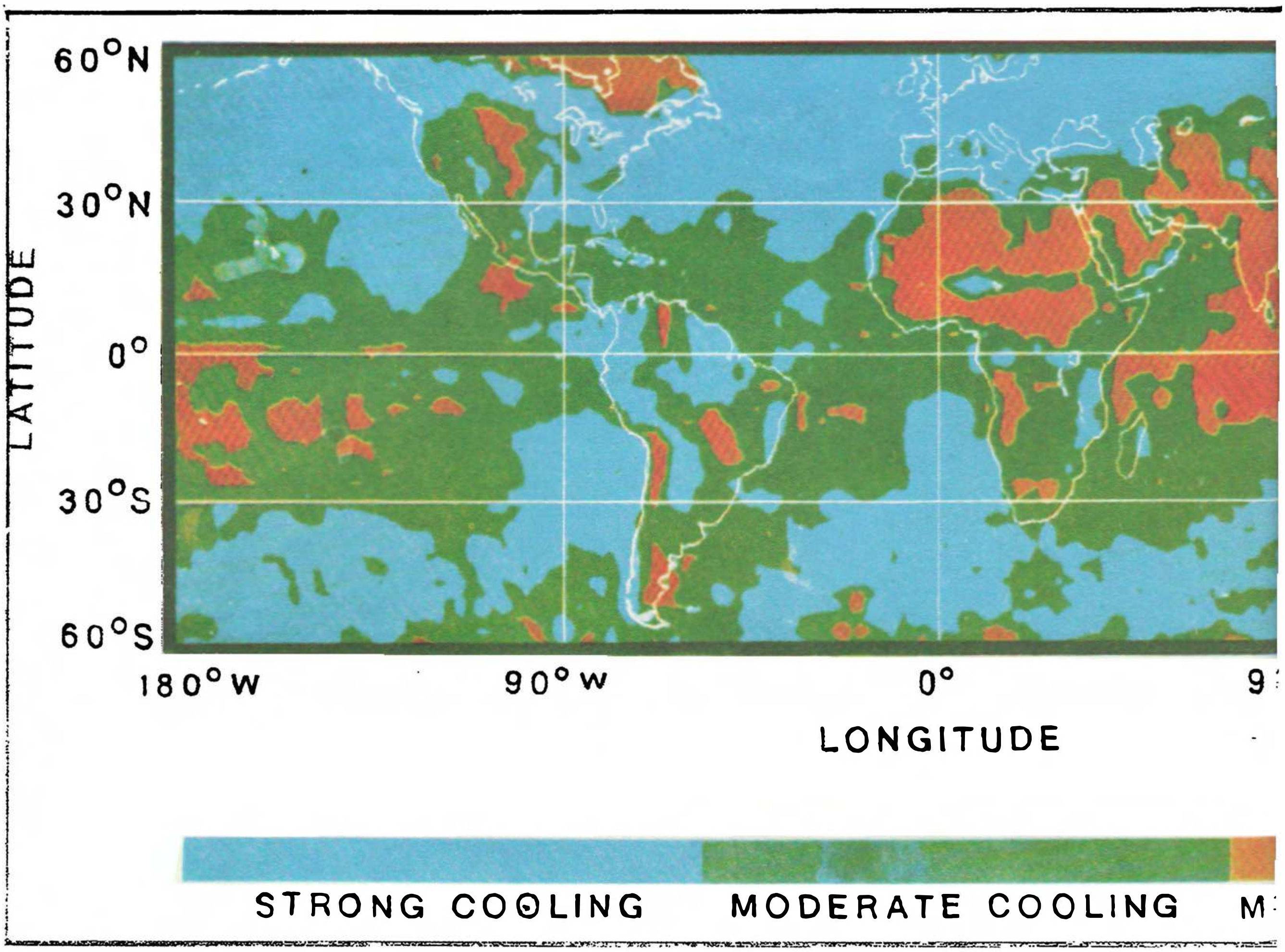
Built by the Hughes Aircraft Company, each GOES (Geostationary Operational Environmental Satellite) has a mass of 442 kg in orbit and measures 3.6 m high and 2.15 m in diameter.

Japan, India and the European Space Agency (ESA) also operate geostationary meteorological satellites. The orbital positions of these satellites, separated by roughly 70 degrees of longitude, are as follows:

GOES (US): 75 degrees W and 135 degrees W.
Meteostat (ESA) 0 degrees.
INSAT (India): 74 degrees E.
GMS (Japan): 140 degrees E.

The primary payload of GOES is the Visible-Infrared Spin-Scan Radiometer Atmospheric Sounder (VAS). Simultaneous visible and infrared images of an entire Earth hemisphere are produced by VAS at 30 minute intervals 24 hours per day. The images can be edited together to produce a time-lapse motion picture of atmospheric circulation. Resolution is 0.9 km for visible light images and 6.9 km for infrared.

The infrared sounding capability of VAS enables meteorologists to construct three-dimensional vertical profiles of the atmosphere. The temperature and



Clouds Cooling and Heating the Earth

Measurements of the Earth and its atmosphere by NASA's Earth Radiation Budget Experiment (ERBE) indicate that clouds may have a significant effect on climate and weather patterns. Preliminary data suggest that clouds reflect more heat than they retain. Clouds appear to cool Earth's climate, possibly offsetting the atmospheric "Green house effect." Shown above is an illustration of the cloud's effect on the Earth's atmosphere, as observed by NASA's Earth Radiation Budget Satellite (ERBS) during April 1985.

altitude of each cloud and atmospheric layer is measured, as well as moisture content. With repetitive soundings, a picture of the dynamical motion of the atmosphere is revealed, permitting forecasters to predict theoretically the movements of weather systems up to several days in advance.

Both types of weather satellites are equipped with Space Environment Monitors to detect charged particles in the vicinity of the Earth. Protons and electrons from the solar wind interact with the upper atmosphere, subtly influencing Earth's weather patterns.

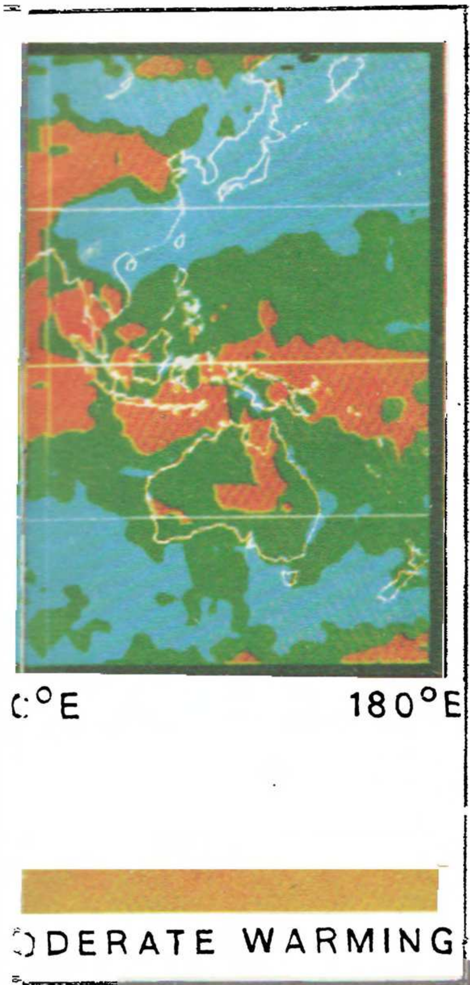
GOES satellites spin at 100 rpm to maintain stability and thermal equilibrium. In order for VAS to produce an image, the sensor must scan a different 8 km strip (or line) of the Earth's disc on each revolution After every scan a stepping motor repositions the VAS mirror until all 1,820 lines are completed, and herein lies a weakness in the system. The stepping motor is controlled by an incandescent encoder lamp and photocell system which measures the angle of the mirror prior to the next scan. The encoder lamps of GOES-2, 3 and 5 all burned out before the end of the seven year design life of the spacecraft, eliminating the spin-scan imaging of VAS.

When GOES-5 failed in July 1984, GOES-1 lasted only seven months as substitute. Solitary coverage of North and South America will be provided by GOES-6 until a replacement (GOES-G) is orbited in 1986. NOAA manoeuvered GOES-6 40 degrees westwards to a more central viewing position over the Americas, but coverage of the Pacific and Atlantic Oceans was seriously restricted as a consequence.

The Ford Aerospace and Communications Corp. recently won a contract from NOAA to provide a follow-on to the present GOES series beginning in 1989. Based upon the Ford-built INSAT communications/weather satellite, the new GOES will be three-axis stabilised and is intended to be launched from the Space Shuttle.

The Soviet Union operates a fully operational weather satellite network in polar orbit. Flying at an inclination of 82.5 degress, the Meteor-2 spacecraft provide much the same imaging and sounding services as the American polar orbiters. The USSR also plans to develop a weather satellite for synchronous or highly elliptical (Molniya-type) orbits.

Technical problems with GMS-2 forced the Japanese to launch their third Geostationary Meteorological Satellite (Himawari) ahead of schedule in August 1984. Future launches include the third European Meteosat on the maiden flight of the Ariane 4 launcher in 1987, to be followed by three 'operational' Meteostats by 1990. The third Indian INSAT was scheduled to be deployed from the Shuttle in July 1986 and China recently announced that it intends to launch a polar orbit weather satellite by 1987.



Space Station Hurricane Alert

by Michael Engle

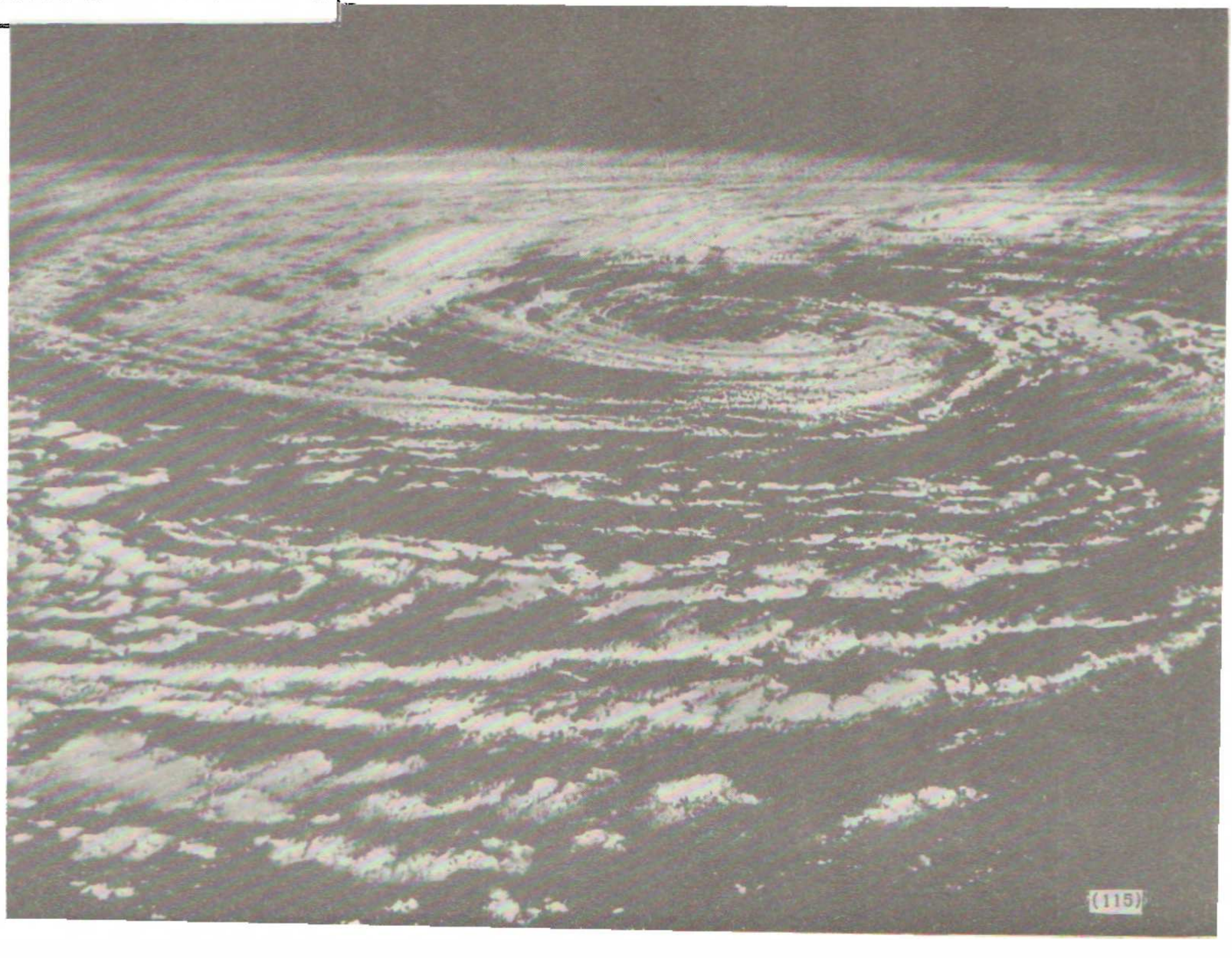
While Shuttle missions have provided a good observation platform for short periods (an average mission lasts seven days), the space station will allow observers to make long term studies of geological, oceanographic, and atmospheric targets. The planned 28.5 degrees inclination orbit of the space station will allow ground coverage from 28.5 degrees north to 28.5 degrees south and one field that will benefit significantly from long-term observations from the space station is the study of the development and structure of tropical storms and hurricanes.

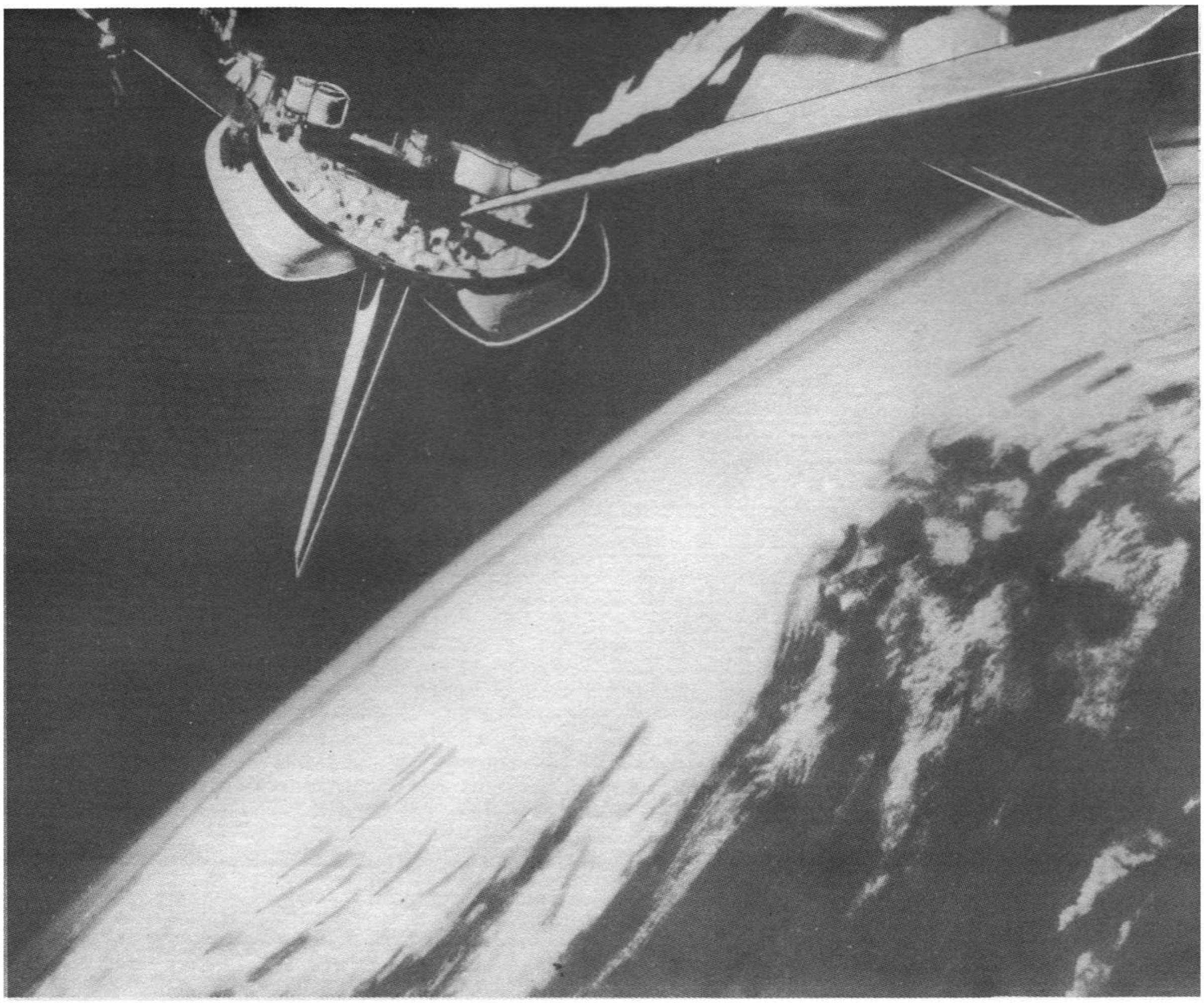
Many of the remote sensing instruments and techniques used aboard the Space Shuttle will be easily adaptable to the space station for use in monitoring hurricanes. For example, the Shuttle Imaging Radar (SIR) produces images (similar to black and white photographs) of ground targets with a resolution of about 15 metres and such a device onboard the space station could yield information on hurricane features such as the amount of rainfall and the roughness of the sea surface.

The Large Format Camera (LFC) is another instrument that could prove useful in space station monitoring of tropical storms and hurricanes. This camera uses a combined high resolution/wide field of view lens, in addition to a large 23 cm x 46 cm film format, to achieve very high quality, high resolution photographs of the Earth's surface. At the space station's planned altitude of approximately 420 km, it would record an area of 315 km x 630 km, sufficient to encompass the ring of maximum winds of most hurricanes.

The space station could also carry many other remote sensing devices. Among them would be a microwave radiometer by which wind speed, water vapour, and rain rate could be

Cyclonic storm north of Hawaii.





A Linhof Aero Technika 4" x 5" film photo of hurricane Josephine off the Florida coast. Meteorologists can tell a lot about a hurricane's structure and development from such photos.

estimated and a narrow beam radar altimeter to measure the roughness of the sea surface, surface currents and average wave height. Also, an infrared radiometer could be used to measure sea surface temperature and a special microwave radar, called a scatterometer, could be used to measure the amplitude of short surface waves that are in equilibrium with the local wind, thereby allowing an estimate of the wind velocity at the sea surface to be made. The instruments required to collect this data could be mounted on a stable pallet attached to the space station and operated by trained experts onboard.

A scenario for such a survey might be imagined as follows:

On August 12, 1995, meteorologists record an easterly wave moving off the coast of Senegal, in Western Africa. This information is relayed to a meteorologist/payload specialist (M/PS) onboard the space station.

Six hours later, during a daylight pass over the target area, the M/PS observes a small group of thunderstorms over the Cape Verde Islands in the eastern Atlantic. The M/PS photographs the region with a handheld 70mm camera, making sure to record images from several different angles as the station passes over the target. He also videotapes the region using video cameras mounted outside the station. The battery of video cameras includes an infrared TV camera, an ordinary colour camera, and a special low light-level camera. The M/PS and an assisting crewmember begin a 24 hour, round-the-clock vigil to record the progress of the potential hurricane. The M/PS also activates a complex array of remote sensing instruments designed to

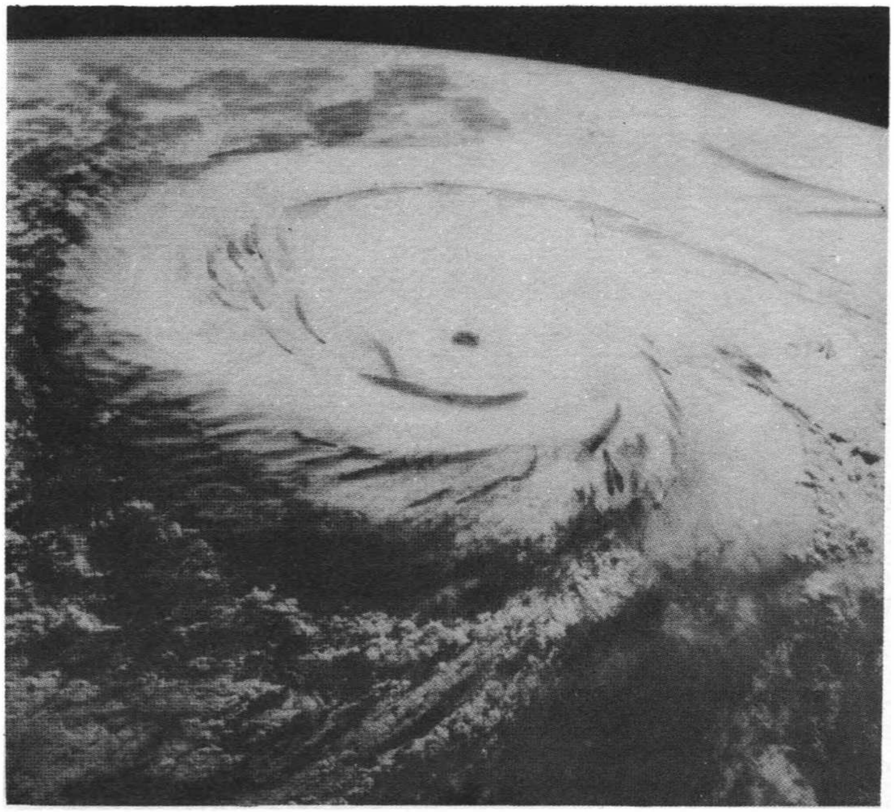
Typhoon Pat in the Western Pacific. Taken with a Hasselblad 70 mm. This is one of a pair of stereo photos that, when taken together, yield much more detail of the three dimensional structure of hurricanes than can ever be obtained from meteorological satellites.

record detailed information about the structure and characteristics of the storm.

On August 14, 1995, a Navy reconnaissance plane reports a poorly defined eye with winds of about 95 mph, some 15° west of the Cape Verde Islands. Onboard the space station, the M/PS continues to observe, photograph, and videotape the developing storm, as well as operate the instrument array mounted outside the station.

By August 15, 1995, Hurricane Danielle has developed into a powerful storm, with the highest recorded winds of 130 mph. Onboard the station, the observers continue to monitor data being recorded by the remote sensing devices mounted outside the station, on a special platform. The platform carries a very narrow beam radar altimeter, a microwave radiometer, a microwave scatterometer, an infrared radiometer, and a synthetic imaging radar. The M/PS records significant data on the station's onboard data recorders, and relays it to meteorologists on the ground, to aid them in making real time assessments of the storm's strength and probable path.

During the next four days, the crew of the space station continues to document the progress of Hurricane Danielle. As the storm continues on a course for the Florida mainland, the M/PS observations assist the ground based meteorologists in predicting the point of landfall.

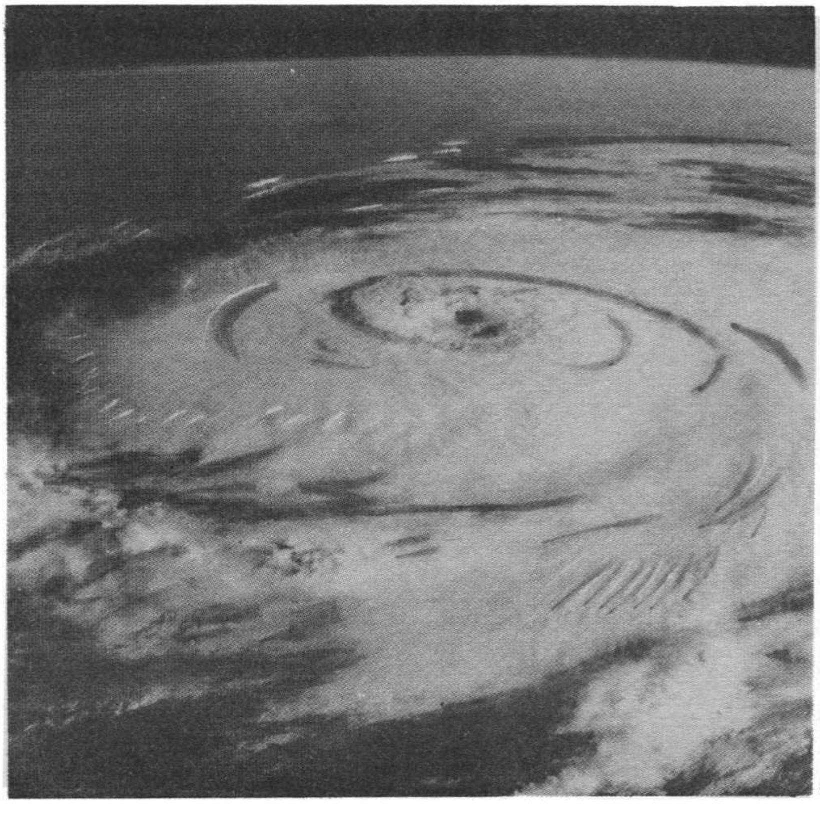


A Hasselblad 70 mm (with 250 mm lens) photo of the eye of Typhoon Pat, taken over the Pacific Ocean. Such detail is impossible to achieve using weather satellites.

On August 19, 1995, Danielle comes ashore near West Palm Beach, Florida, causing extensive damage. Fortunately, there is sufficient advance warning to allow residents to prepare, and no lives are lost. Meanwhile, the crew of the space station continues to observe Danielle's progress over the Florida landmass, where it begins to lose strength.

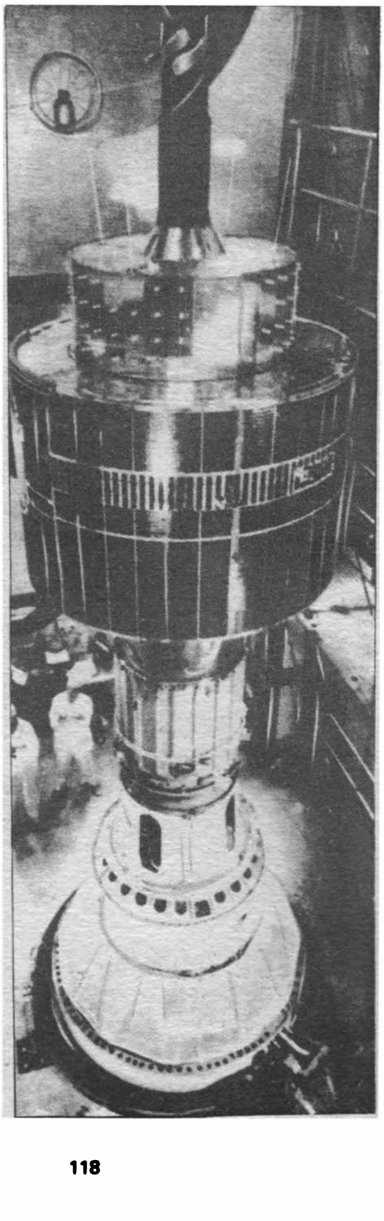
As Danielle slowly dissipates, the observers document her final hours. For the first time the birth, life and death of a major hurricane has been thoroughly recorded from the vantage point of space.

Oblique view, taken with a Hasselblad 70 mm, of Hurricane Elena. Note the detail visible in the spiral bands and eye of the storm.



While weather satellites are useful in studying the large scale features of tropical storms, their high altitude orbit (over 32 000 km) prohibits a detailed study. Also, in order to truly understand hurricanes and tropical storms, visual observations must be supplemented with data on sea and air temperatures, wind velocities and their gradients, surface currents, upper altitude winds, and amounts of rainfall. This data could then be used to develop a data base for computer modelling of hurricane development and to predict factors that initiate and sustain the growth of hurricanes and tropical storms. Obviously, the space station can play a major role in increasing our understanding of the formation and life cycle of tropical storms and hurricanes. A greater understanding of these storms will undoubtedly lead to better predictions, which in turn will decrease the tragic toll of lives and money lost to these storms nearly every year. This alone may well justify the next step in America's space programme – a permanent manned presence in space.

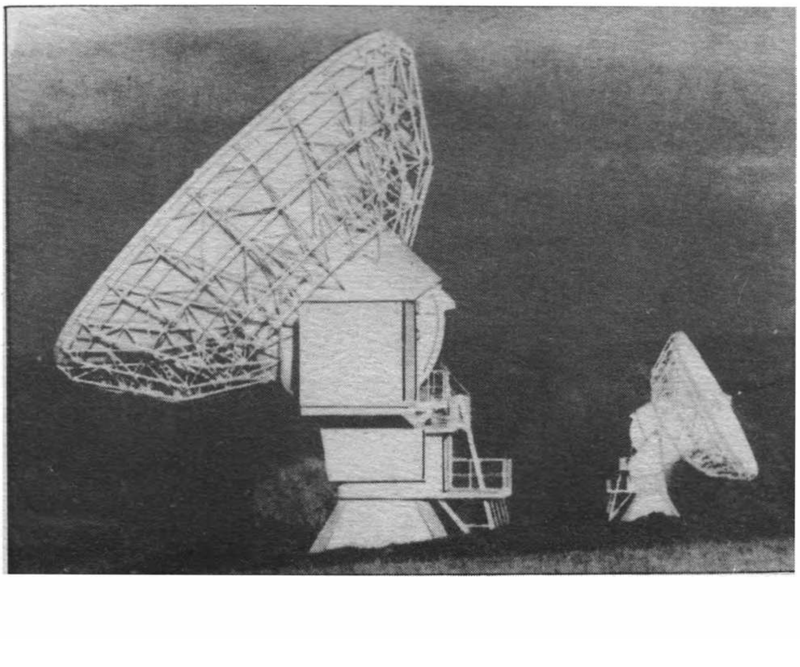
Visible light Meteosat image (above) compared to a specially processed view (right) to highlight water vapour in the atmosphère.



Meteosat 1, assembly with launcher.

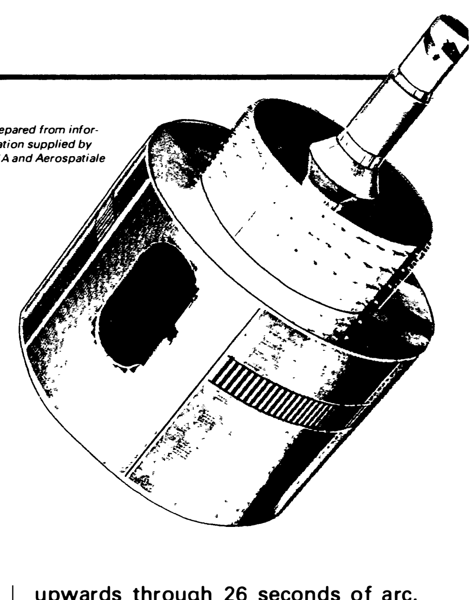
Meteosat picture in the visible range (left) compared to Meteosat picture in the infrared range (right).

Meteosat ground station at Michelstadt/Odenwald.



METEOSAT

Prepared from information supplied by ESA and Aerospatiale



Meteosat is one of five geosynchronous satellites participating in World Weather Watch that are positioned equidistantly above the equator and are backed up by several polar transiting satellites providing the complementary weather data that the goesynchronous type cannot supply. All the information gathered by the WWW satellites is sent to a centre in Reading, UK, where it is processed.

Most well-known of all satellite data are the spectacular images of the Earth's cloud cover that appear in TV weather bulletins all over the world. But the satellites' main mission is to collect digital data from which a mathematical model of atmospheric movements can gradually be built up. Several years' worth of stored data will enable meteorologists to make ever more accurate long-term weather forecasts.

The first Meteosat satellite (Meteosat F1), launched in November 1977, suffered a partial electrical malfunction two years later, after which it was unable to continue with its imaging missions. The F2 replacement was launched by Ariane L03 in June 1981 and has been operational ever since, except for its beacon interrogation capability. Combining F1 and F2 made it possible to fulfill all the Meteosat missions until 1985 when F1 had to be deactivated after its fuel supply ran out.

Since then, a European space meteorology agency (Eumetsat – see ***Spaceflight***, Feb. 1987 p.52) has been founded and this organisation has placed an order with Aerospatiale for three new operational Meteosat satellites. Launches are due to begin later this year so that there will be no break in the service.

Furthermore, the European Space Agency (ESA) has requested a refurbishment of the P2 prototype (a satellite which was built ten years ago) so as to make it flightworthy once more. This flight model is booked for launch on the first Ariane 4 flight and should therefore be on station before the end of the year, ready to serve as relay between Meteosat F2 (which has been in orbit for almost six years) and the first satellites in the new operational series.

The Meteosat system has three prime missions: to provide images of the Earth in the form of quantified data, data collection and data dissemination.

It is made up of a space segment (initially with one satellite, then two) and a ground segment comprising various elements.

ESA was responsible for initiating the programme and financing it as from 1973 as part of its optional programmes. Eight European nations participated (Germany, Belgium, Denmark, France, the United Kingdom, Italy, Sweden and Switzerland).

Following a call for bids, prime contractorship for the satellite was awarded by ESA to Aerospatiale as head of the Cosmos consortium whose other members were Siemens and MBB (W. Germany), ETCA (Belgium), Selenia (Italy), Marconi (UK), and Matra, Crouzet and SAT (France).

The satellite has a cylindrical body 2.1 m in diameter and 3.2 m high. Once in orbit, it is spun up on its axis to 1000 rpm and this endows it with the required gyroscopic stability to perform its mission as a spin-stabilised satellite. The satellite's spinning motion also enables it to carry out line-scanning of the Earth's surface by means of the telescope housed in its body.

The main payload is a radiometer comprising a Ritchey-Chrétien telescope with an aperture of 40 cm which rotates about an axis perpendicular to the satellite's spin axis. Sensors located in the telescope's focal plane supply remote-sensing data in the visible, thermal infrared and water vapour absorption frequency bands. Cooling for the infrared sensors is provided by a passive radiator that radiates into deep space at four degrees Kelvin.

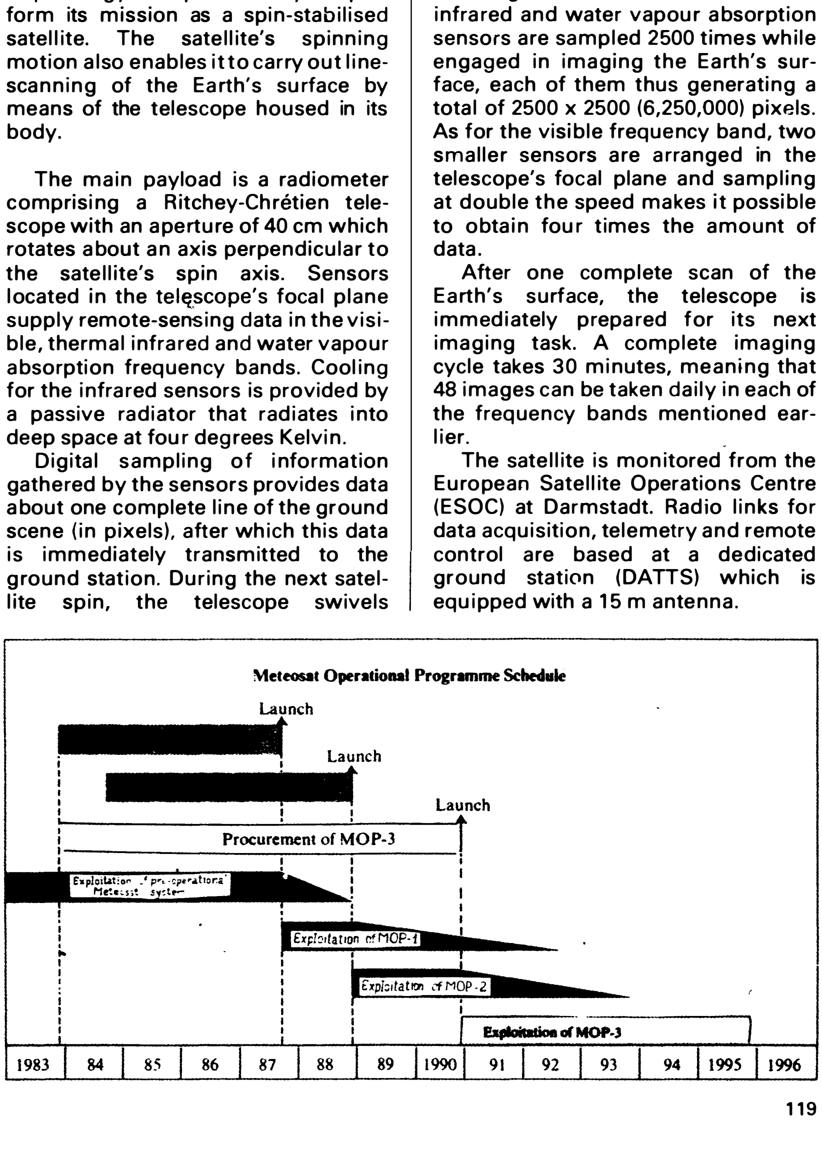
Digital sampling of information gathered by the sensors provides data about one complete line of the ground scene (in pixels), after which this data is immediately transmitted to the ground station. During the next satellite spin, the telescope swivels upwards through 26 seconds of arc, and as soon as the Earth comes into its field of vision again it images another line contiguous with the preceding one.

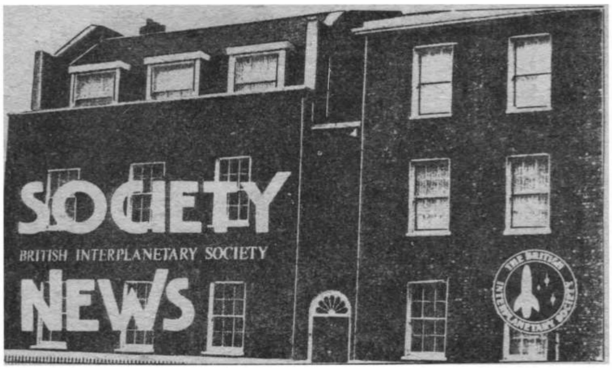
The telescope swivels in this way a total of 2500 times, making it possible in the space of 25 minutes to cover the Earth's surface in a series of 2500 lines of images. Data from the thermal infrared and water vapour absorption sensors are sampled 2500 times while engaged in imaging the Earth's surface, each of them thus generating a total of 2500 x 2500 (6,250,000) pixels. As for the visible frequency band, two smaller sensors are arranged in the telescope's focal plane and sampling at double the speed makes it possible to obtain four times the amount of data.

After one complete scan of the Earth's surface, the telescope is immediately prepared for its next imaging task. A complete imaging cycle takes 30 minutes, meaning that 48 images can be taken daily in each of the frequency bands mentioned earlier.

The satellite is monitored from the European Satellite Operations Centre (ESOC) at Darmstadt. Radio links for data acquisition, telemetry and remote control are based at a dedicated ground station (DATTS) which is equipped with a 15 m antenna.

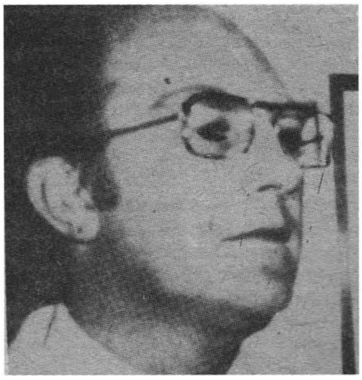
Meteosat Operational Programme Schedule





International Academy of Astronautics

Recent elections to Membership of the International Academy of Astronautics include many Society Fellows and others closely associated with the Society. We are pleased to include in this issue short biographies of two of the new members and extend our congratulations to them on the receipt of this honour.



Antony Smith.

Antony John Smith is an Independent Management Consultant on effective project management.

His career has been devoted to the efficient planning and control of all types of projects covering such aspects as guidance systems, electronic business machines, aerospace and defence projects as well as space projects.

These activities have been undertaken all over the world resulting in a current travel programme of nearly 200,000 miles per year.

Space related projects have included early work with the European Space Research Organisation on Ariel One, guidance systems projects for Black Night and Blue Streak, satellite work in Australia as well as work with NASA on the manned space flight programmes at Houston, Texas.

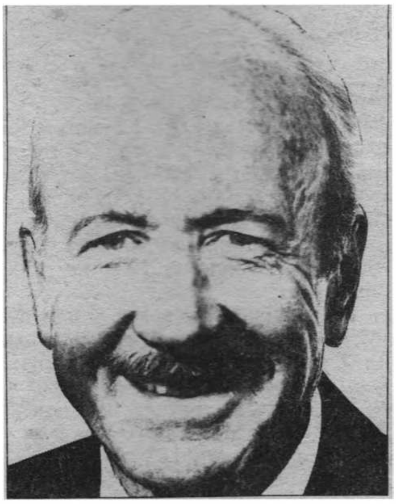
The IAA was founded in 1960 by the International Astronautical Federation as an independently constituted body. It is devoted to fostering the development of astronautics for peaceful purposes, recognising individuals who have distinguished themselves in a branch of science or technology related to astronautics. The Academy organises international symposia and produces the monthly journal, Acta Astronautica.

Its first Director was the eminent aerodynamicist Theodore von Karman. In 1963 the title of Director was changed to President. The current president is Dr. George E. Mueller, who is distinguished for his direction of the Apollo Project of manned lunar exploration.

The NASA activities started four years ago as a result of work with DoD and defence contractors. He was asked by the Director of the Johnson Space Center to act as principal consultant on projects covering the National Space Transportation System (NSTS), Space Station and other operational contracts.

The specific advice given is in the area of performance management which is very important given the emphasis placed on the cost effective management procedures required by the US Government.

Currently, Mr. Smith is acting as an advisor for numerous companies around the world and anticipates increased involvement with NASA once the current situation has stabilised.



Philip Culbertson.

Philip E. Culbertson was appointed to the position of Associate Administrator for NASA Policy and Planning on January 9, 1987. In this position he will direct a policy and planning staff providing support to the Office of the Administrator in policy analysis and the programme and institutional planning processes.

Mr. Culbertson was the General Manager for NASA from December 1985 to January 1987. As General Manager, he served as the principal assistant to the Administrator with responsibility for providing general management of the agency within established policies. From August 1, 1984 to December 1985, he was the Associate Administrator for Space Station.

He was the Associate Deputy Administrator from November 1981 to August 1984. Earlier assignments within NASA included the positions of Assistant for the Space Transportation System, advising the Administrator of STS matters requiring policy decisions; Deputy Associate Administrator for Space Transportation Systems (Technical); Assistant Administrator for Planning and Programme Integration; and Director of Advanced Manned Missions. He joined NASA in 1965 having been previously employed by General Dynamics Corporation in San Diego, California.,

Mr. Culbertson was born in Colfax, Washington. He attended Washington State University, Pullman, Washington; Millsaps College; Jackson, Mississippi; and received a Bachelor of Science degree in aeronautical engineering from Georgia Tech. He served as a commissioned officer in the US Navy after which he spent four years at the University of Michigan as a graduate student and Research Associate, receiving a Master of Science degree in aeronautical engineering. He received the Presidental Rank Award of Meritorious Senior Exeuctive in 1982 and that of Distinguished Executive in 1983. He has, in addition, received the NASA Distinguished Service and Exceptional Service medals. He is an officer and a Fellow in the American Astronautical Society.

He and his wife, Shirley, reside in McLean, Virginia. They have a daughter, Camden Gooch, and a son, Philip, Jr.

Coat of Arms

Arms of The British Interplanetary Society.

The Society has been honoured by a grant of arms and heraldic badge by The College of Arms, which has recently prepared the designs shown on this page.

The arms, which appear here on the shield, are an heraldic interpretation of the Society's present logo, first introduced in 1954 following an invitation to members to submit suitable designs.

The three stars derive from those on the logo which were introduced to represent the Society's association with 'earth-space, near-space and deep-space'. The two vertical bands and the zig-zag transverse band on the shield are intended to convey the shape of two rockets, being inspired by the winged rocket on the logo.

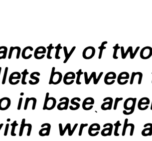
The design is in line with heraldic convention by using only basic heraldic divisions of the shield and accords with the heraldic tradition of concealing actual meaning. In colour, the stars and bands are in white on a background of blue, which is the Society's traditional colour.

The demi-winged horse of the crest commemorates the astronautical achievements of transport and communication in space exploration. The horse provided man with his speediest means of transport and communication over many past centuries. The addition of wings represents the same role in a celestial environment. The laurel wreath round the horse's neck is a symbol of honour and achievement, recognising the honour due to those who have pioneered astronautical achievements. The area of achievement is here reflected by the astral crown supported by the winged horse. The heraldic interpretation of an astral crown is that of pre-eminence 'among the stars'.

The shield is supported by two winged lions. The lion is a British national symbol. The lions also serve to locate the shield in space by the fact that they are winged, stand on a mound of clouds and look rearwards, the inference being that of looking towards the Earth from space.

The Society's motto, incorporated in the coat of arms, is ***From Imagination To Reality***. It expresses a fundamental character of the Society in its continued close association with pioneering achievements throughout its existence. The motto itself comes from the subtitle of the Society's book *High Road to the Moon* (1979) which records much of its early work and ideas on rocket and satellite developments, leading to exploration of the Moon and beyond, and shows how so many of these ideas were subsequently realised, particularly with the Apollo programme.

The heraldic badge has a simple and striking design based on the astronomical symbol for a comet. Comets are singularly unique. They are natural travellers of interplanetary space journeying from its outermost to its innermost regions and also possibly into interstellar regions. The design therefore provides a most appropriate symbol of the Society's aims.



The Society's comet badge.

Readers with a special interest in heraldry might like to know that the armorial bearings are blazoned as set out below. Others may be simply bemused by an almost archaic wording peculiar to a subject steeped in history.

Arms: *Azure a fess dancetty of two points conjoined to as many pallets between three mullets one in chief and two in base argent.*

Crest: *Upon a helm with a wreath argent and azure a demi horse argent winged gorged with a laurel wreath and supporting between its hooves an astral crown all gold.*

Badge: *The astronomical symbol for a comet in bend sinister argent.*

Supporters: *On either side a winged lion regardant gold the compartment comprising clouds proper.*

Motto: *From Imagination to Reality.*

JUST ASK . . .

Copies of a Society leaflet publicising ***Spaceflight*** are freely available to members for distribution. ***Spaceflight*** may now be obtained by either bookstall purchase (in the UK) or annual Society membership (world-wide). Please take every opportunity to bring ***Spaceflight*** to the attention of others.

Members can provide invaluable support for the Society by mentioning its work whenever the opportunity arises and by introducing new members. Free literature about the Society, including the ***Spaceflight*** leaflet, may be obtained at any time by contacting the Society.

LIBRARY OPENING DAYS

The Society Library will be open to members from 5.30 p.m. until 7 p.m. on Wednesday March 11, 1987. From April onwards it will be open on the first Wednesday of each month (except August) at the same times.

WANTED – OLD MAGAZINES

The Society always welcomes the return of back issues of ***'Spaceflight'*** and ***'Space Education'*** which members no longer require and uses these to help newer members complete their sets, replace copies in Public Libraries, etc.

At present we particularly seek ***'Space Education'*** Vol. 1, No. 4 (1982) and would like to hear from any member with one to spare. Please write to: BIS Administration Office, 27/29 South Lambeth Road, London, SW8 1SZ.

QUICKER DELIVERY FOR JBIS

Overseas readers who receive ***JBIS*** on annual subscription can look forward to a much quicker delivery service. Following the successful introduction of ***Spaceflight*** delivery by accelerated surface mail to overseas addresses, the arrangement is to be extended to ***JBIS*** as soon as possible. It will be introduced without extra charge and will be available to annual subscribers of ***JBIS*** only.

SOCIETY MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

11 March 1987, 7-9 p.m. — Lecture

WHEN IS SPACE NEWS?

by F. Miles

Once, in the days of Apollo, there was tremendous television and press interest in space. Now it seems to take something like the Challenger disaster to arouse media interest. What *are* the constraints on reporting space news? How *do* editors decide what is worth reporting? Frank Miles has been handling space stories on ITN since the 1960 — and might have some answers.

29 April 1987, — Symposium

FUTURE SPACEPLANES

A follow-up to the successful Hotol Symposium in November 1986. 'Future Spaceplanes' will be held at Millbank Tower, London SW1. Registration 9am, first lecture 9.30am. Programme to be announced shortly. Registration forms available from The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

6 May 1987, 7-9 p.m. — Lecture

REVIEW OF THE SOVIET SPACE PROGRAMME

by P.S. Clark

For more than a decade, in terms of launch rates, the Soviet Union has dominated space activity. Many aspects of its space programme are shrouded in secrecy but a careful study of public information allows insights to be obtained into Soviet space programmes. Phillip Clark has been analysing the Soviet Programme for nearly two decades, and will present a review intended for the non-specialist of recent development and the future direction of the programme.

6 June 1987 — Symposium

SOVIET ASTRONAUTICS

Offers of papers are invited. Society members with a special interest in the Soviet Space Programme are invited to attend the symposium to be held at the BIS HQ, London. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose a stamped addressed envelope.

10-17 October 1987 — Congress

38th IAF CONGRESS and SPACE '87 EXHIBITION

Invited lectures, Symposia and over 600 technical papers will be presented. To be held at Brighton, England, hosted by the British Interplanetary Society. To go on the mailing list for free information send your name and address to: "38th IAF Congress", The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

Targeting Neptune

The engineering essence of the mission of Voyager 2 to Uranus consisted of upgrades to an old spacecraft and provisions for successfully imaging the satellite Miranda at close range (see the November 1986 issue of *Scientific American* for details). The focus for the Neptune mission is, at this time, the selection of a trajectory which will yield maximum science return consistent with safety.

Trajectory selection at Uranus was not a major issue because the aim point was tightly constrained by the necessity to receive a gravity assist from Uranus for the passage to Neptune. Voyager 2 has no planetary encounters after Neptune so a similar constraint does not exist for the August 1989 flyby of that planet.

The trajectory family which furnishes the basis for the best observations of Neptune and its large satellite, Triton, poses potential hazards to the spacecraft and its proper functioning from trapped radiation, ring material, and interactions with the Neptunian atmosphere. The geometry for this family features a very close overflight of the north pole of Neptune, bending the spacecraft's path southward for a close approach to Triton five hours later.

The task before the Voyager Project is to validate the above "north polar crown" targeting zone with respect to feasibility and to select the best trajectory which penetrates this region. These and related topics were reviewed in depth at a November 17 meeting of the project's Science Steering Group. Charles Kohlhase, manager of the Voyager Mission Planning Office, participated in this review and discussed with your correspondent some of the key issues involved in the emerging trajectory selection.

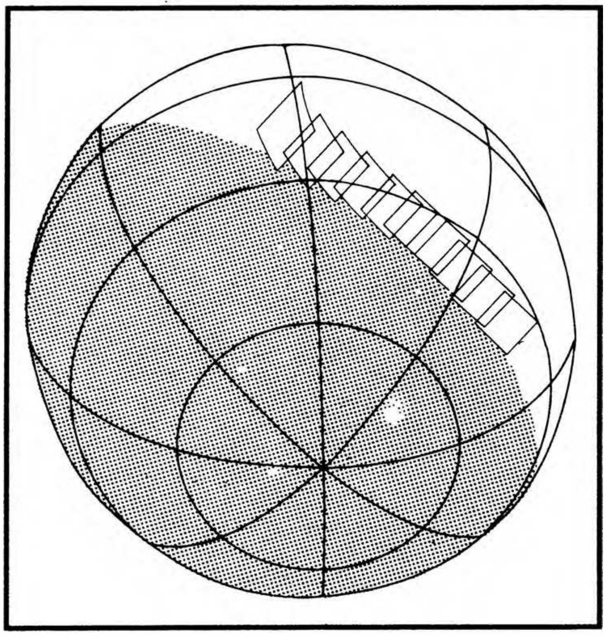
The investigations which primarily motivate the north polar crown strategy are: (1) deep penetration of Neptune's probable magnetosphere to measure a variety of field and particle interactions, (2) refraction of radio waves through the atmosphere of Neptune for reception at Earth in order to deduce atmospheric properties such as temperature, pressure, and density (see the June 1986 edition of this column for the counterpart investigation at Uranus), (3) a related radio-science experiment for Triton – one of the major points of interest in the Neptunian system is the atmosphere of this body, a feature common only to Titan (Saturn's largest satellite) among the satellites of the solar system, (4) observations of the Sun through the atmosphere of Neptune, then Triton, by the ultraviolet spectrometer in order to measure structural and compositional parameters, and (5) imaging at close range the surface of Triton.

Geometrically, the radio-science investigations of the atmospheres of Neptune and Triton require occultation of the Earth by these bodies, as seen from the spacecraft, because the spacecraft broadcasts radio energy to antennae located on Earth. The geometry of the ultraviolet measurements is dictated by the need of occulting the Sun since the data from this experiment are recorded on the spacecraft rather than on Earth. The imaging experiment thrives on closeness to the object to be imaged, Triton, for increased resolution of surface features.

Another geometrical factor arises from limits on the accuracy with which the spacecraft's antenna can be pointed. If, for example, the spacecraft were too close to Neptune during the conduct of the radio-science experiment – which consists of tracing out about 20 straight-line segments along the limb of the planet while broadcasting radio waves from the spacecraft's antenna – pointing errors could degrade the results.

No one trajectory would prove optimal for the

Shown are footprints on Triton of the narrow-angle camera of Voyager 2 during the planned closest imaging of this large satellite of Neptune, at a range of about 40,000 km. The images will reveal objects down to 0.8 km and are placed along the terminator to take advantage of the favourable lighting angles in this region. As with the close-in imaging of Miranda at the Voyager 2 Uranus encounter, it will be necessary to perform a late update of camera pointing angles and image-motion-compensation rates of the spacecraft (to prevent image smear due to the rapid relative motion between satellite and spacecraft). The update reflects the latest navigational information. The remainder of the terminator region will be captured in subsequent images.



accomplishment of all these scientific objectives, and, in addition, the previously mentioned hazards of atmosphere, rings, and radiation modulate the decision. The nature of these three hazards will now be examined in turn.

Normally, the atmosphere of a planet is only of *scientific* interest during a Voyager flyby, but in order to achieve enough trajectory bending from Neptune to pass closely to Triton it is necessary to fly quite near to the planet. Consequently, several engineering effects due to the interaction of spacecraft and upper atmosphere must be evaluated: heating through friction (which would adversely affect the performance of Voyager 2's delicate radio receiver), loss of attitude control through atmospheric torques, perturbation of the trajectory with a resultant effect on accurate pointing and measurement of gravitational harmonics, electrical arcing induced by the atmosphere, and disturbance of the spacecraft's thermal blankets which assist in temperature control.

Each of these potential sources of trouble determines a minimum distance from the centre of the planet below which the spacecraft should not be targeted.

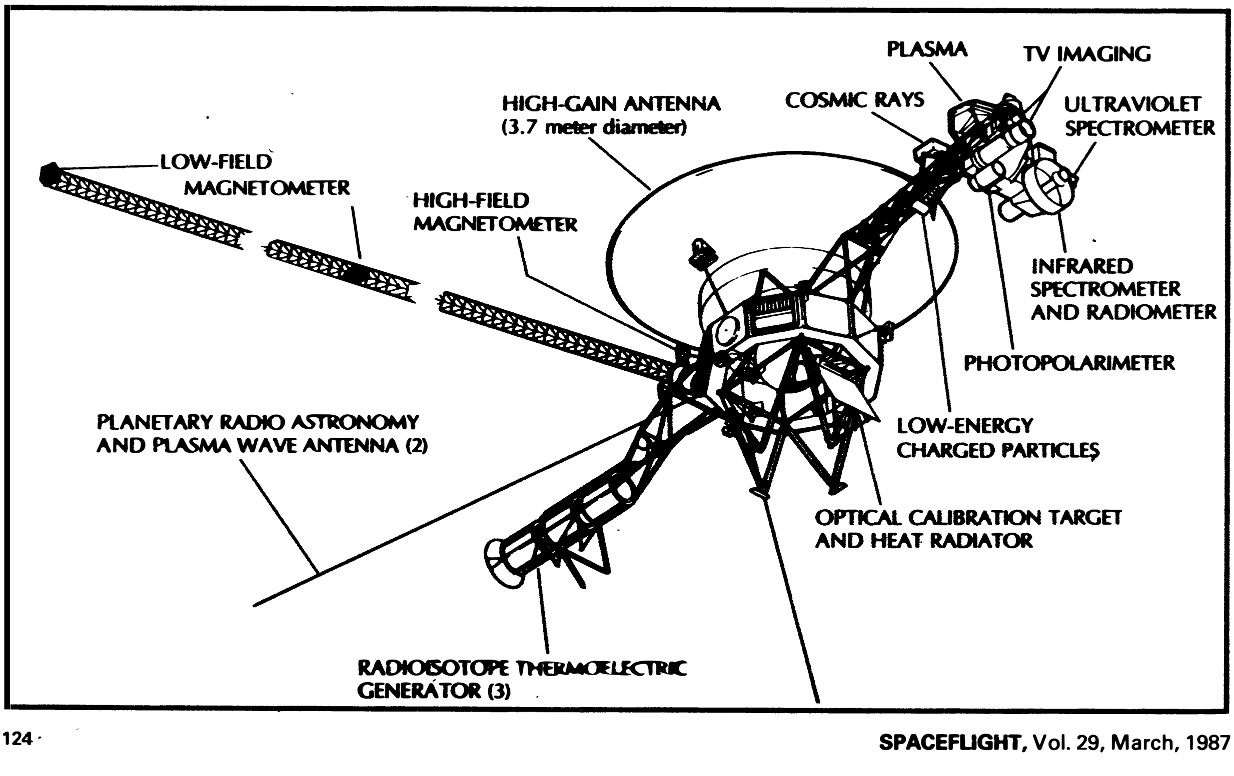
For their analyses, project engineers utilised a model of the Neptunian upper atmosphere based upon an assumed temperature of at most 500 degrees K. Although the temperature of the upper Uranian atmosphere was found to be 750 degrees K, the scientists have predicted a lower figure for Neptune, partly from observations conducted from the International Ultraviolet Explorer (IUE) satellite. In this isothermal region of the upper atmosphere, a lower temperature is more favourable for the mission because it implies that the atmosphere, whose density falls off exponentially with distance, will not extend its denser regions as far out into space as a more heated atmosphere would (technically, the scale height is reduced at lower temperatures).

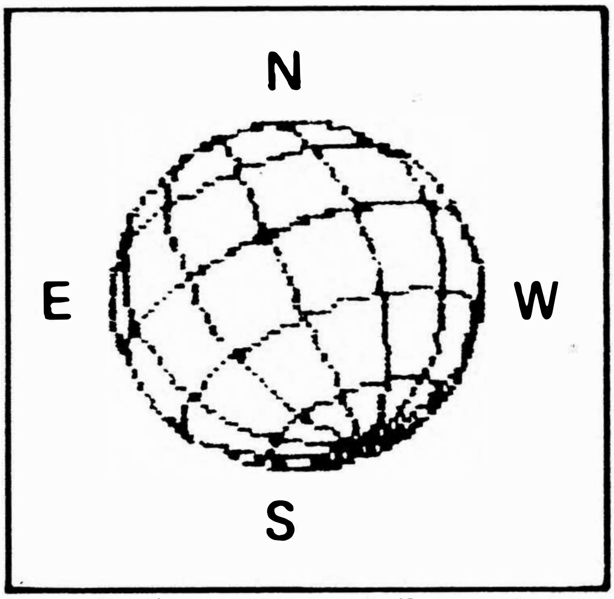
It was determined that the controlling atmospheric factor on trajectory selection is the electrical arcing which could result from ionization of the atmosphere near the spacecraft by the rapid passage of the vehicle. However, the risk is avoided if the trajectory is chosen so as to pass more than 27,300 km from the centre of Neptune. Neptune, being a gas giant, has no observable surface, and this distance corresponds to about 3000 km above the 100-millibar pressure level of the atmosphere: approximately where the cloud tops lie. At this distance from Neptune the spacecraft would later fly by Triton at a range of 23,000 km (Voyager 2 approached to within 29,000 km of Miranda at Uranus).

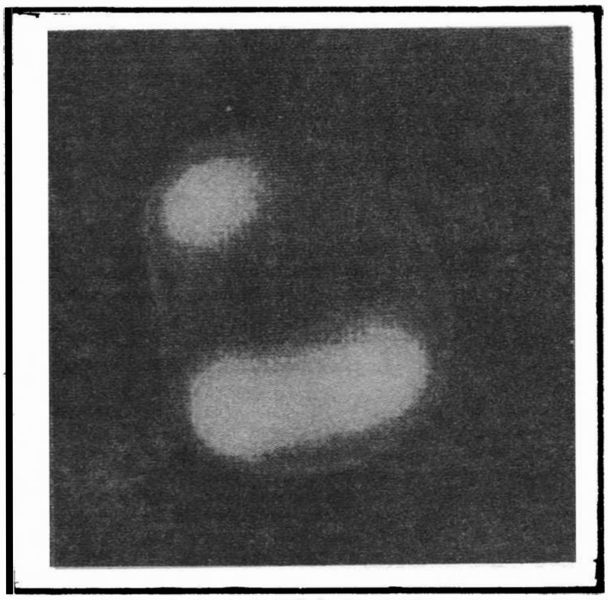
The structure of the rings of Neptune is not well known, unlike the Uranian rings which had been accurately mapped from Earth prior to the Voyager encounter. Best current estimates suggest that there are two nearly circular rings which lie near the equatorial plane of Neptune at distances of 56,500 ± 2500 km and 67,000 ± 4000 km. Each ring may consist of partial arcs of material, separated by empty regions which could add up to 95 per cent of the circumferences. The rings, like those of Uranus, appear to be quite narrow, perhaps extending only eight to 20 km in radial width. One hypothesis has been advanced that the stellar-occulation data, which form the basis for Earth-based ring studies, are better fit by polar rings! But the Voyager team feels that the equatorial model is more plausible.

There is not much concern that the spacecraft would hit one of these narrow rings. Kohlhase calculates that even if, perversely, we targeted the vehicle to hit a ring there is less than a 10 per cent chance we would be "successful". Concern does exist that diffuse material near the rings would furnish a hazard. It is felt that such material is most likely to be migrating inward, toward the planet, although drag from corotating plasma could push material outward. Hence, the ring-avoidance strategy that has been adopted is to target the spacecraft so that it passes through the equatorial

Main features of the Voyager spacecraft.







Three bright cloud features – each about the size of Earth – are visible in this image of Neptune taken on May 25, 1983 with the 2.5m telescope at Los Campanas Observatory in Chile. A charge-coupled device (CCD) and planetary coronagraph were employed by Dr. Richard Terrile (JPL) and Dr. Bradford Smith (University of Arizona) in obtaining this image. The clouds probably consist of methane ice crystals elevated above most of Neptune's gaseous atmosphere. Studies of these features show that they move around the planet about every 17 hours and 50 minutes. *NASA/JPL*

plane of Neptune farther than 71,000 km from the planet; 67,000 km represents the outer ring's distance, with 4000 km added in to allow for the uncertainty of the ring's location. This yields a flyby distance (at closest approach) of 28,950 km from Neptune, which entails a later flyby of 38,500 km from Triton. Thus, the hazard associated with the rings imposes a more severe constraint on the mission than that arising from the atmosphere.

The most serious threat might come from high-energy particles trapped in the magnetic field of Neptune, should that planet, like Jupiter, Saturn and Uranus, possess such a field. The proposed close encounter with Neptune could deeply immerse the spacecraft in the swirl of electrons, protons and heavy ions that probably gird the planet. The greatest concern is with electrons having energies of over three million electron volts. This trapped radiation could affect the spacecraft through two mechanisms: flux and fluence. "Flux" refers to the intensity of radiation measured at any one time, while "fluence" denotes the integrated effect of exposure to radiation. As demonstrated at the Voyager 1 encounter with Jupiter's intense radiation belts in 1979, these effects can cause problems. One particular worry is possible disturbance of the spacecraft's timing source, which would throw the planned sequence of observations into disarray. One does not want, for example, to be opening the shutter of a camera before the camera is pointed at its target!

The spacecraft was "flown" through the radiation model which engineers think is most likely to represent the Neptunian environment, and this mathematical simulation showed that problems should not be expected, either from flux or fluence. However, a worst-case radiation model showed a peak flux which reached six times the highest level at Jupiter and a fluence one half of the Jovian value experienced by Voyager 1. Neither figure is very reassuring. The results are only weakly sensitive to the exact trajectory that is flown within the north polar crown family, hence unlike the atmospheric and ring hazard studies, no limits on flyby distances have been quoted.

Further studies are underway to see if the worst-case model is indeed a possible state of affairs. Several experts believe it to be unduly conservative. In any case, there are methods that can be employed to help "bullet proof" the near-encounter sequence; certain software subroutines can be loaded into the spacecraft's computers to compensate for most timing problems.

The Science Steering Group has weighed the science return and safety factors, sketched above, and reaffirmed the north polar crown strategy. Its scientific value is considerably greater than alternative, more conservative, approaches (which we did not describe due to lack of space). The specific trajectory which has been selected approaches to within 29,000 km of Neptune, so atmospheric and ring hazards are minimal, and passes by Triton at 40,000 km. It represents a good compromise between Neptune and Triton atmospheric science objectives (radio and ultraviolet studies) and Triton imaging-science objectives. If the aimpoint were much further from Neptune it can be shown that, considering navigational uncertainties, it would be difficult to place the spacecraft so as to achieve occultations of both the Sun and Earth by Triton. Occultations by Triton are, in any case, somewhat uncertain with respect to present-day knowledge of that satellite's radius. It is estimated to be 1800 km but could be 700 km greater or smaller. A smaller value for the radius of Triton would, of course, make occultation of Earth and Sun more difficult to achieve. If the aimpoint were any closer to Neptune, it would become more difficult, as previously mentioned, to lay down an accurate 20-segment pattern along the limb of Neptune for radio-science studies of the atmosphere. Although the Imaging Team would prefer a Triton flyby distance of about 25,000 km, the 40,000 km approach will still yield excellent resolution, good viewing and lighting conditions, and relatively low smear rates.

On March 13 a trajectory correction manoeuvre (TCM) is scheduled to advance the arrival time of Voyager 2 at Neptune by 12 hours from its current mark. The new time will be 0400 GMT on August 25, 1989, as

measured at the spacecraft. The arrival time is important because Triton must be in the proper location in its orbit so that the dual encounter, with Neptune and Triton, can be executed as planned. At the same time that this timing adjustment is being made, the aim point will be shifted from its present location to one nearer the desired point.

However, the TCM is not designed to put the spacecraft on target exactly toward its final aim point close to Neptune. The interim aim point has been selected so that if no more TCMs could be performed, there would exist no more than a 10 per cent chance of impacting Neptune with the spacecraft as a result of targeting uncertainties. Recall that one of Voyager 2's radio receivers failed in 1978, and if the remaining one should also fail no further commands, including those associated with subsequent TCMs, could be accepted by the spacecraft. The concern for impact with Neptune does not come from a biological quarantine of the planet; unlike Mars, contamination is a negligible concern by NASA. Rather, the spacecraft carries a backup mission load (BML) which would allow it to carry out, autonomously, a minimal observational programme at Neptune should its receiver fail. In case of impact, the post-Neptune portion of the BML-guided programme would be lost, including Triton close-up studies. Although the probability of occurrence of such a scenario is small, the precaution illustrates the extreme importance with which this once-in-a-lifetime encounter is regarded by the Voyager Project.

Geometry Serves Science

Dramatic events in space missions come readily to mind: touchdown on Mars by the Viking Landers, the discovery of active volcanoes on the Jovian satellite Io by Voyager 1, and the detection by IRAS of solid material circling the star Vega. What is not so apparent is the vast river of technical, scientific data that flows from each mission through the scientific community, enriching the understanding and forming the basis for new insights into the universe in which we live.

Recognition of the importance of these data and the difficulty in utilising them efficiently was made in 1978 when the Space Science Board of the US National Academy of Sciences formed the Committee on Data Management and Computation (CODMAC). Over the years, through a series of reports, CODMAC has proved to be an influential force in shaping the way that NASA develops its information systems. The first CODMAC report was approved by the Space Science Board in October 1980 (copies are available from the Space Science Board, 2101 Constitution Avenue, Washington, D.C. 20418).

The planets and the oceans, lands and atmosphere of the Earth have been served by CODMAC. Among the information-oriented entities of NASA that can trace at least part of their origins to CODMAC are: the Planetary Data System, the NASA Ocean Data System, the Pilot Land Data System ("Pilot" signifies "prototype" in this usage and was, also, formerly associated with the planetary and ocean data systems), and the Pilot Climate Data System.

Of course, the focus of all of these data systems is the primary, scientific data which they contain. However, one of the problems identified by CODMAC was, "Data archives generally contain insufficient ancillary data such as time, attitude, orbit, or sensor calibration data." In a broad sense, the geometrical and engineering environment must be characterised along with the actual scientific measurements. It is to this effort, the Navigation Ancillary Information Facility (NAIF), part of the Planetary Data System, that we now turn.

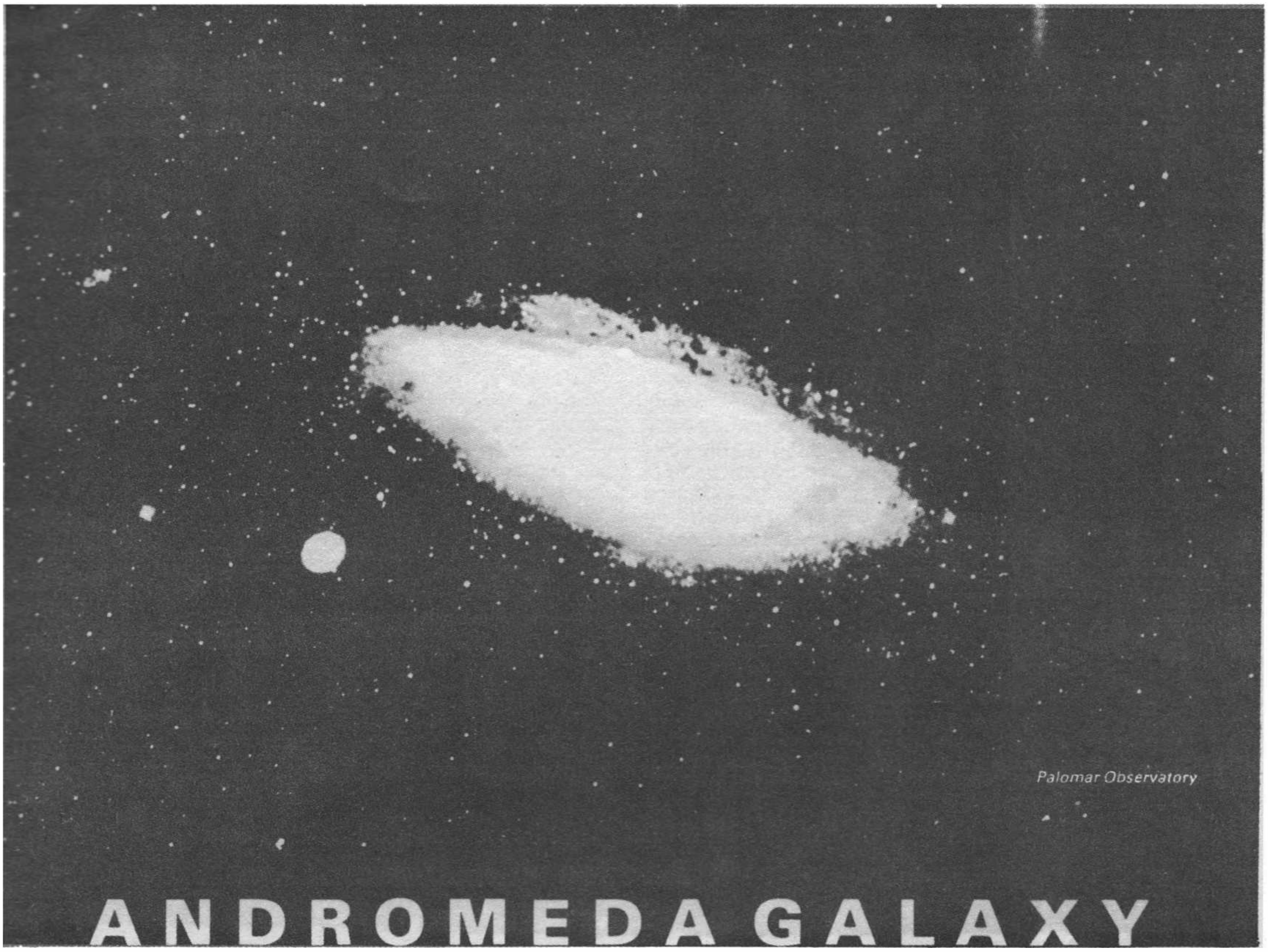
The idea of supplying ancillary data to scientific investigators is certainly not new; for years JPL has been producing the Supplementary Experiment Data Record (SEDR) to accompany the primary Experiment Data Record (EDR). Generally, a flight project has a Data Management Team which, among other tasks, is charged with generating SEDRs. The common practice is to furnish a SEDR in two stages: a predicted SEDR, prior to the event, and the post-event SEDR. These SEDRs, customised to the various investigations on board the spacecraft, contain, as relevant, information about the direction of pointing of the instrument as a function of time, the ephemeris of the spacecraft and target objects, the state of the instrument, and much more.

But there are problems associated with this system. After a lapse of some years, it is very difficult to go back to the data base of a former project and understand it to the degree that is usually necessary to support a follow-up investigation. For example, the direction of the spin axis of Mars was revised during the Viking mission, and data dependent upon latitude and longitude must be scrutinised in an attempt to ascertain which Martian pole was used for their calculation.

Another problem is that scientific investigators must specify early in the life of a project exactly which quantities they wish to be contained in their SEDRs – flexibility is limited with this system. The timeliness of SEDR deliveries is, upon occasion, not well coordinated with an experimenter's needs. The SEDRs for a planetary encounter are available about one month after that event, too late to support the customary 30-day scientific report and sometimes too early to take advantage of the highest-accuracy engineering processing that eventually becomes available, such as precision orbit determination by the project's Navigation Team.

The NAIF approach addresses these and other problems by producing a standardised system, with provisions for flexibility and timeliness, that addresses the areas of ancillary data calculation, assembly, archiving, distribution and accessing.

A demonstration of some aspects of the NAIF capability was held during the Voyager 2 encounter with Uranus last year. The objective was to process as many images from the Voyager cameras as quickly as possible in order to determine accurately the direction of camera pointing. Of the pictures delivered to the NAIF team, 93 per cent were processed within 32 hours of receipt, and the level of absolute pointing accuracy that was determined by the processing greatly exceeded the usual standards. Pointing was generally determined to within five or 10 pixels (picture elements); each image from the Voyager narrow-angle camera is composed of 800 x 800 pixels, the totality of which span a 0.424 degree field-of-view. Thus, the demonstration effectively addressed timeliness and accuracy, for some of the Voyager data.



ANDROMEDA GALAXY

Andromeda, the M31 galaxy, is the great spiral galaxy nearest to the Milky Way. The great nebula in Andromeda is shown in visible light (top) and in the infrared (bottom). The ring of dust that shines brightly in the IRAS infrared picture is seen only in silhouette in the visible photograph of the galaxy. Stars that are bright in the visible are virtually invisible in the infrared image.

NAIF techniques have also proved useful for calculating pointing directions for non-imaging instruments such as the ultraviolet and infrared spectrometers. Normally, the pointing is calculated from information based upon star-tracker, Sun-sensor, and electromechanical data relayed to Earth via the spacecraft's telemetry stream. The pointing of an instrument is specified by three angles: two which measure the direction of the boresight (right ascension and declination) and one the "twist" angle of the field-of-view.

Consider the plot of one of these angles – right ascension, declination, or twist – as a function of time, as determined from spacecraft telemetry. At certain times during the period of time of this plot, images may have been taken from another instrument (the camera), and, if the pointing direction of the camera can be accurately determined at these times, as during the Uranus/NAIF demonstration, the whole set of (non-imaging) data can benefit. The improvement in accuracy for the non-imaging plot is possible because the boresight of the camera and other remote-sensing instrument on Voyager are closely related by virtue of the residence of these instruments on a common scan platform. The NAIF processing just takes the existing telemetry-derived curve which forms the plot and moves it around as if it were a rigid object, until it most closely passes through the few pointing angles/times determined by the camera. In this way, the absolute accuracy of the original plot can be greatly improved.

The technique is rather enigmatically referred to as "C-smithing" – the enigma is removed when one learns that the "C matrix" is the name for a mathematical device used by JPL engineers to specify pointing.

Flexibility and responsiveness are being built into NAIF through the construction of a library of programs (NAIFLIB, as the acronym expert could guess) which will be made available to scientists for processing data within the NAIF data base. The individual scientist can then decide whether to tailor ancillary data to his needs, through factoring in, or not, niceties such as aberration and light-time corrections, or to accept the more standard package which will still be produced by JPL. For this approach to work, the NAIFLIB software must be portable (able to function on the computer at any installation) and intelligible. The first requirement is being met by writing the code in a near-universal language, FORTRAN 77, while the attention to the second embeds a guide to users directly into the listing of the code, rendering the documentation always current with respect to the code. Since NAIFLIB is to be used, at their option, by scientists, they are heavily involved in consulting roles during design and implementation. Historically, partnerships between science and engineering, when formed, have proven to be a powerful combination. The Infrared Astronomical Satellite (IRAS) was an extremely successful mission, and it can be argued that much of this success was due to the close interaction, before and after launch in 1983, between scientists and engineers in designing the data system, the strategy for the all-sky survey, and the hardware for the (unexpectedly challenging) focal plane and dewar.

A second Voyager demonstration of NAIF will probably be conducted at the Neptune encounter in 1989. An increased level, over Uranus, of real-time services would be made available to scientists. The first project to employ NAIF as an integral part of its data service may be the Mars Observer, scheduled for operations in the first half of the next decade.

An important postscript to NAIF arises from use of the geometrical capabilities for planning observations rather than just annotating them afterwards. The Hubble Space Telescope (HST), scheduled for launch into Earth orbit on a Shuttle in 1988, has a strong orientation toward extra-Solar System astronomy: stars, galaxies, nebulae. However, observation of moving Solar System objects will also be necessary. Some NAIF software has been adapted for HST to search for geometrical events of interest to astronomers: occultations, close approaches, maximum elongations, zero apparent motion, etc.

NAIF is managed by Charles H. Acton of JPL, to whom thanks are due for discussions on this topic.

A Martian Balloon

The case for Mars has been building up over the last few years: powered by symposia, studies, papers, articles in the popular literature, the Soviet mission to Phobos in 1988, and the US Mars Observer spacecraft to be launched early in the next decade. One suspects that the next big step in space, comparable to Apollo, may be the manned exploration of Mars. But the definitive vision of such a programme has not emerged from the welter of possibilities, and potential components of the endeavour are undergoing scrutiny and testing. Last month we looked at the role of balloons in a Venus sample return mission; this month a Mars balloon will be examined, along with associated field tests that have recently been carried out in the California desert.

A double balloon for Martian exploration has been proposed by Dr. Jacques Blamont of the French space agency CNES. The first balloon is closed and filled with helium, about 2000 m^3. It provides a relatively stable amount of buoyancy for the system. The second balloon of 3800 m^3 capacity, either suspended below the first, or surrounding it, is a solar montgolfier with a large opening at the bottom which permits the flow of Martian atmosphere (mostly carbon dioxide) in and out. Joseph and Jacques Montgolfier invented the first practical balloon, a large linen bag inflated with hot air, which they sent up at Annonay near Lyons on June 5, 1783.

At Martian sunrise the gas within the black montgolfier begins to heat up and, with the influx and heating of additional atmosphere, the system will begin to rise when its buoyancy equals its weight. The ascension, initially at the slow rate of 1 m/s, could carry the system to a height of 6 km in temperate Martian latitudes. Throughout the Martian day the system might fly, as the winds direct, over 500 km. As the Sun sets, the buoyancy of the montgolfier decreases, and at twilight a landing is made. However, the helium balloon maintains both balloons above the surface: only the tethered payload and a guide rope rest upon the surface of Mars.

During the night-time, tactile experiments in the payload operate on the surface. Daylight hours permit high-resolution observation of the surface from a camera under the balloon. Tactile sensing can also be performed during the day by venting a sufficient amount of gas from the montgolfier to let the tethered payload drag upon the ground. The payload and guide rope also assist in altitude control; when they come in contact with the ground, balloon weight is relieved and the system tends to rise. The virtue of including the montgolfiere in the system can be seen in this ability to lower altitude by venting at will without depleting non-renewable consumables such as ballast and nonambient gas. In fact, the lifetime of the system, estimated to be about ten days, is limited either by battery lifetime or by the loss of helium resulting from diffusion through the skin of its balloon.

Since the programme for Martian exploration is still under development, it is not possible now to place the hybrid balloon system within the context of a total effort. However, it is clear that this system could contribute significantly to the collection of scientific data and would be synergistic with a Mars rover vehicle. The most valuable characteristic of the system is that it provides detailed looks at widely separated places. Clearly, this is important either for scientific studies or for gathering data to plan rover expeditions (or site selection for a Mars lander).

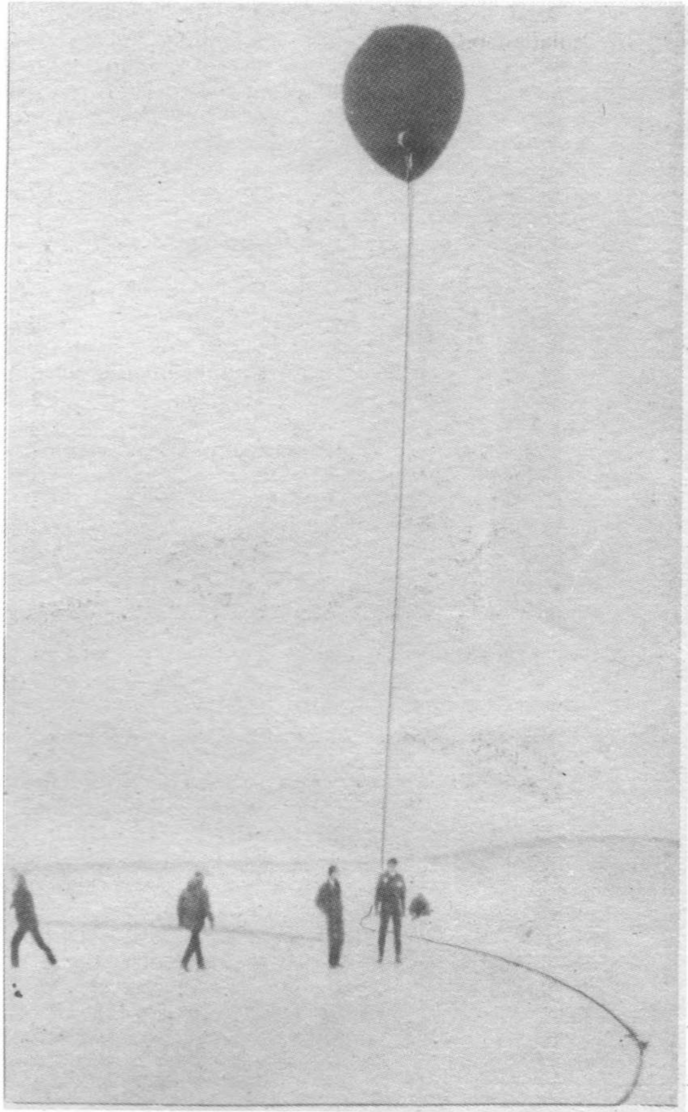
A typical payload has been described by Blamont in order to carry out the main objective – study of the ground: a device for magnetotelluric sounding to define the depth of the permafrost, maybe 1 km (*tellus* is Latin for "earth" or "ground"); a differential thermal analyser for measuring the water content of the regolith; a package for chemical analysis; a magnetometer to measure the crustal magnetic field; and the camera. The total payload, including the camera, is estimated to have a mass of only 6 kg. The location of the system as a function of time could be determined by Earth-based radio tracking.

A prototype of the dual-balloon system has been built by a California team (using a montgolfier supplied by CNES) and is undergoing tests at Edwards Air Force Base in order to better understand its performance characteristics. Dr. Bruce Murray, Professor of Planetary Science at Caltech and former Director of JPL, Thomas Heinsheimer of Titan Sytems, Inc., and a JPL group led by James Burke, including Dr. Gail Klein of JPL, and their test team chose this location for its large-scale flatness, which allows uninhibited tracking of the balloon system with a pursuing ground vehicle.

The configuration for these tests featured the helium balloon inside the montgolfier. The purpose was to conduct timing of ascents and descents, the latter to verify that landings would be gentle enough with regard to the payload, and to become acquainted with the general flight properties of the system. The efficacy of the system was demonstrated by ascent to 100 m in 23 seconds, under conditions of only 30 per cent sunlight, and soft touchdowns which were judged to pose no hazards to a payload.

The second set of tests, in January 1987, utilised an external helium balloon and tested a quick relief valve for control of the montgolfier. In addition, temperature sensors were placed in the interior of the montgolfier to facilitate engineering studies.

The advent of balloons and (solar) sails in the forefront of advanced space studies is a testimony to the durability of these venerable modes of transportation.



Tests were conducted in California on December 17, 1986 of a prototype montgolfier balloon system that is a candidate to be a component in a Mars exploration system.

CASE FOR MARS

Conference, July 18-22, 1987.

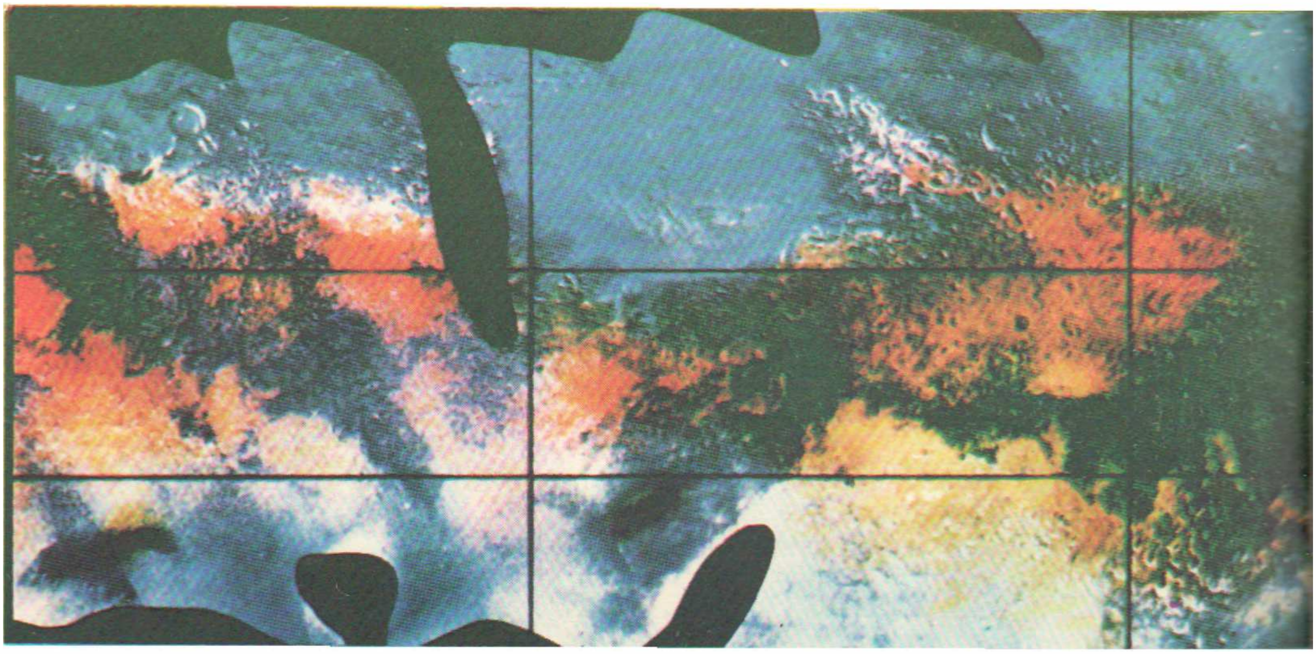
How and when the exploration of Mars is to be undertaken depends on the development of viable strategies. The third in this series of conferences, The Case for Mars III, will focus on strategies for exploration. Special emphasis will be put on examination of international programmes as a way that Mars exploration might be carried out.

The conference will be held at Boulder, Colorado under the chairmanship of Thomas Paine, a former NASA administrator, who chaired the US National Commission on Space which in April 1986 presented its report, 'Pioneering the Space Frontier: Our Next 50 Years'.

Details of the conference programme and submission of papers may be obtained from: Case for Mars III, P.O. Box 4877, Boulder, CO 80306, USA. Tel: (303) 494-8144.

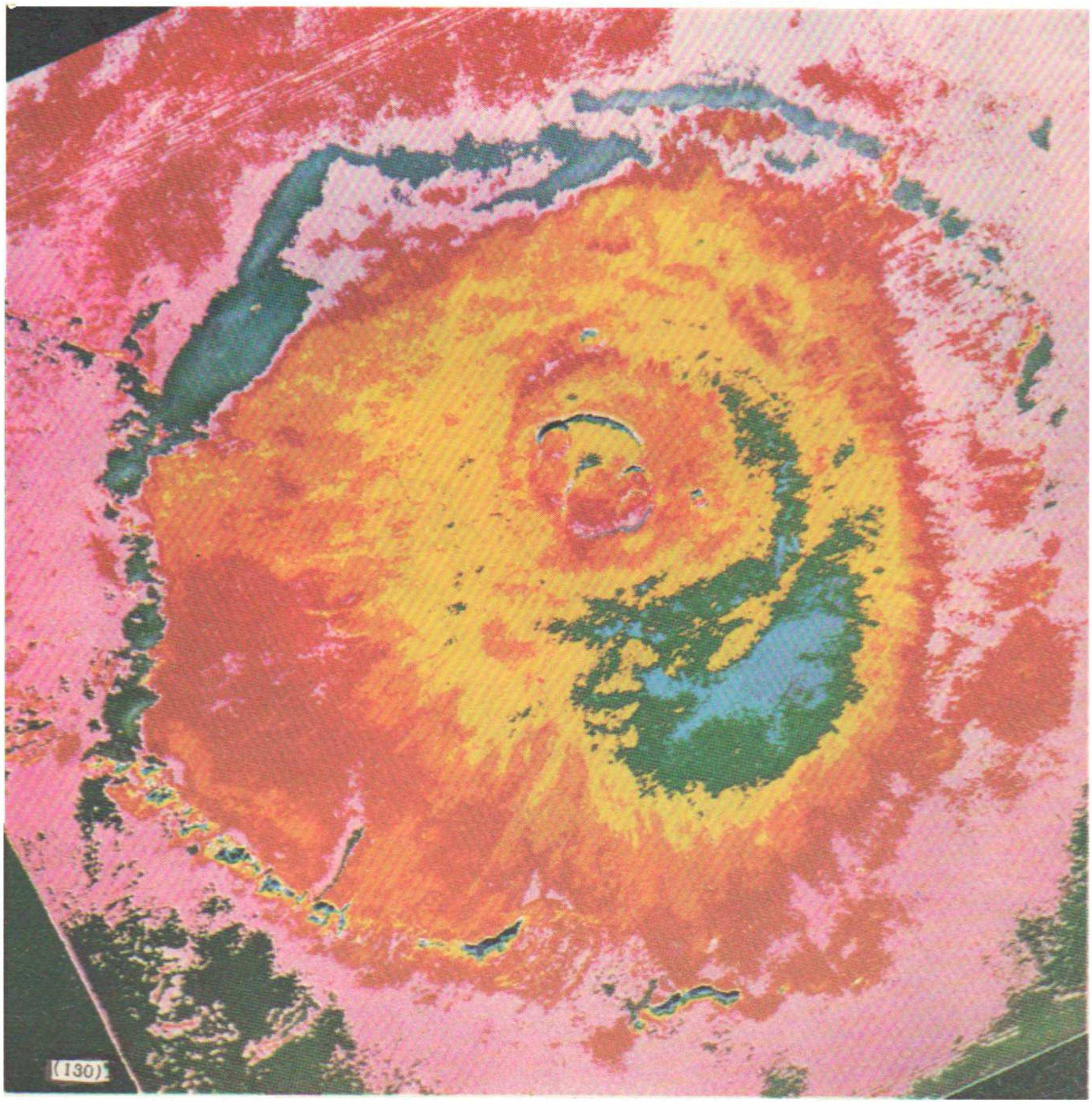
A New World to Explore

With the Viking spacecraft, a wealth of new information was revealed about Mars. From the mass of scientific photographic records, ***Douglas Arnold*** describes overleaf three Mars pictures that he finds of special interest.



Pictures Space Frontiers NASA

Viking lander.



MARS – A New World to Explore

***Douglas Arnold* selects three pictures from the era of spacecraft exploration of Mars to which image processing has introduced a new, and possibly abstract, appearance in contrast with the harsh reality of space conveyed by the photographs on pages 106 and 107.**

False colour enhancement is a long established tool in the technology of remote sensing from space – be it of the Earth or other planets. Generally the aim is to discriminate with greater clarity differences of surface tone, texture or colour which are not easily apparent in the original scene. Such representations frequently assume an abstract form.

The picture at bottom left is a false colour treatment by the US Geological Survey at Flagstaff, Arizona of Mars' massive shield volcano Olympus Mons (the largest volcano discovered in the Solar System to date) which rises to more than 16 miles above the planet's mean surface elevation. The different colours exaggerate the very subtle differences in lava flows that have accumulated over time.

Another false colour rendering of part of the surface of Mars made at the USGS in Flagstaff is shown at top left. As it approached Mars in August 1976 the Viking Orbiter 2 took 50 pictures which were used to make this computer generated mosaic illustrating variations in the planet's surface chemistry.

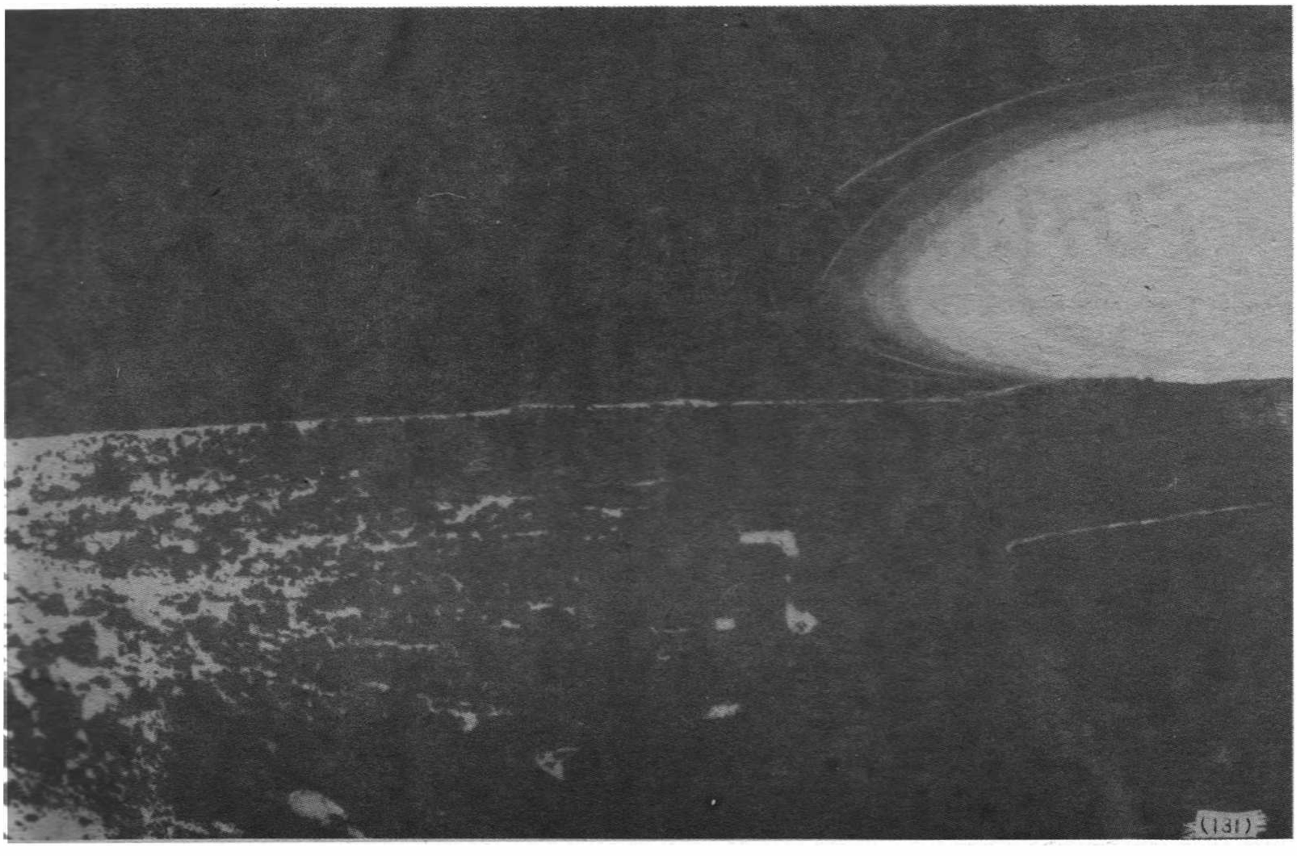
Red depicts rocks that contain a high proportion of iron oxides and dark blue signifies fresher, less oxidised materials which are probably volcanic basalts. Bright turquoise shows surface frosts and fogs derived from carbon dioxide or water ice. Brown, orange and yellow represent different types of sand and dust deposits. This swath covers the entire 360 degrees of planetary longitude between a maximum of 30 degrees N to 60 degrees S.

H.J.P. (Douglas) Arnold

In 1974, Douglas Arnold left Kodak to establish his own company, Space Frontiers, which is a technical consultancy, editorial bureau and photo library devoted to space flight and astronomy

In his earlier career he graduated at Wadham College, Oxford and became a Russian specialist in the Army Intelligence Corps before joining The Financial Times where he eventually became Foreign News Editor. later he joined Kodak as an assistant to the managing director and it was during this time that he developed a specialist knowledge of space imaging techniques

The Viking 1 spacecraft records sunset over the Plain of Gold (Chryse Planitia) on Mars – August 20, 1976. The beautiful haloes in the sky of this computer enhanced view do not exist in reality and resulted from the manner in which the electronic camera systems aboard the Vikings separated different light intensities. One of the robot lander's cameras began scanning the horizon from the left about four minutes after the Sun went down, continuing for ten minutes and covering 120 degrees. The data was then transmitted back to Earth via a radio link with the companion Viking orbiter above.



APRIL 1987 $3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone 0344-884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by Unwin Brothers Ltd., Old Woking, Surrey, England.

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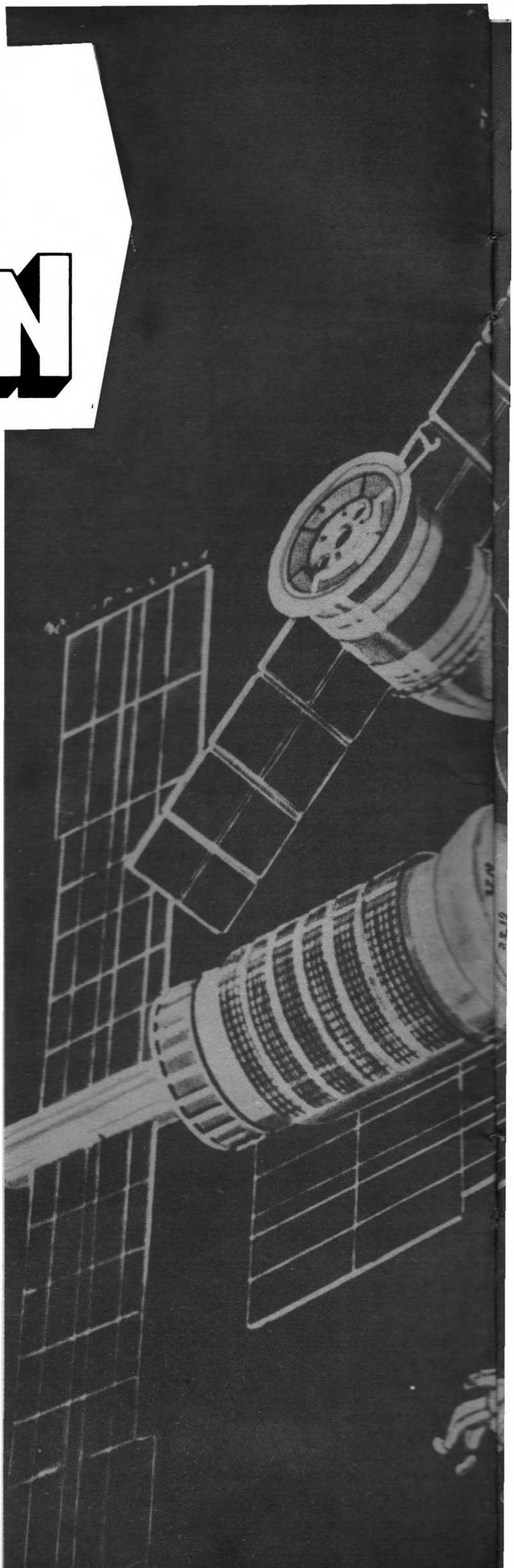
Vol. 29 No. 4 — April 1987

Front Cover: The eighth N-II launch vehicle carrying Japan's Marine Observation Satellite (MOS-1) lifted off from NASDA's Osaki launch site on February 19. Using three on-board sensors, MOS-1, Japan's first Earth observation satellite, will observe marine phenomena, vegetation and land usage. *Report page 138.* *NASDA*

MIR IN ACTION



This is the Soviet modular space station Mir as it may look in the configuration it will grow to over the coming months and years.

The painting, by British Interplanetary Society Fellow Peter Smoulders, is one of the first detailed illustrations published in the West of the complex.

At present only the core Mir module is in orbit, manned by cosmonauts Yuri Romanenko and Alexander Laveikin. Additional space station modules are now being prepared for launch. Usually these modules will first dock to the front docking port of the core vehicle and then manoeuvre to one of the radial ports with the help of a manipulator on each module.

The first additional module will be devoted to astrophysics. Modules for geophysical research, biological research and materials processing will be added later, according to Soviet officials.

In this drawing the six docking ports of the Mir core are occupied by a Soyuz TM, four special modules (redially arranged) and an astrophysics module, to which a Progress is docked. Two of the special modules have solar panels like the two on the core vehicle.

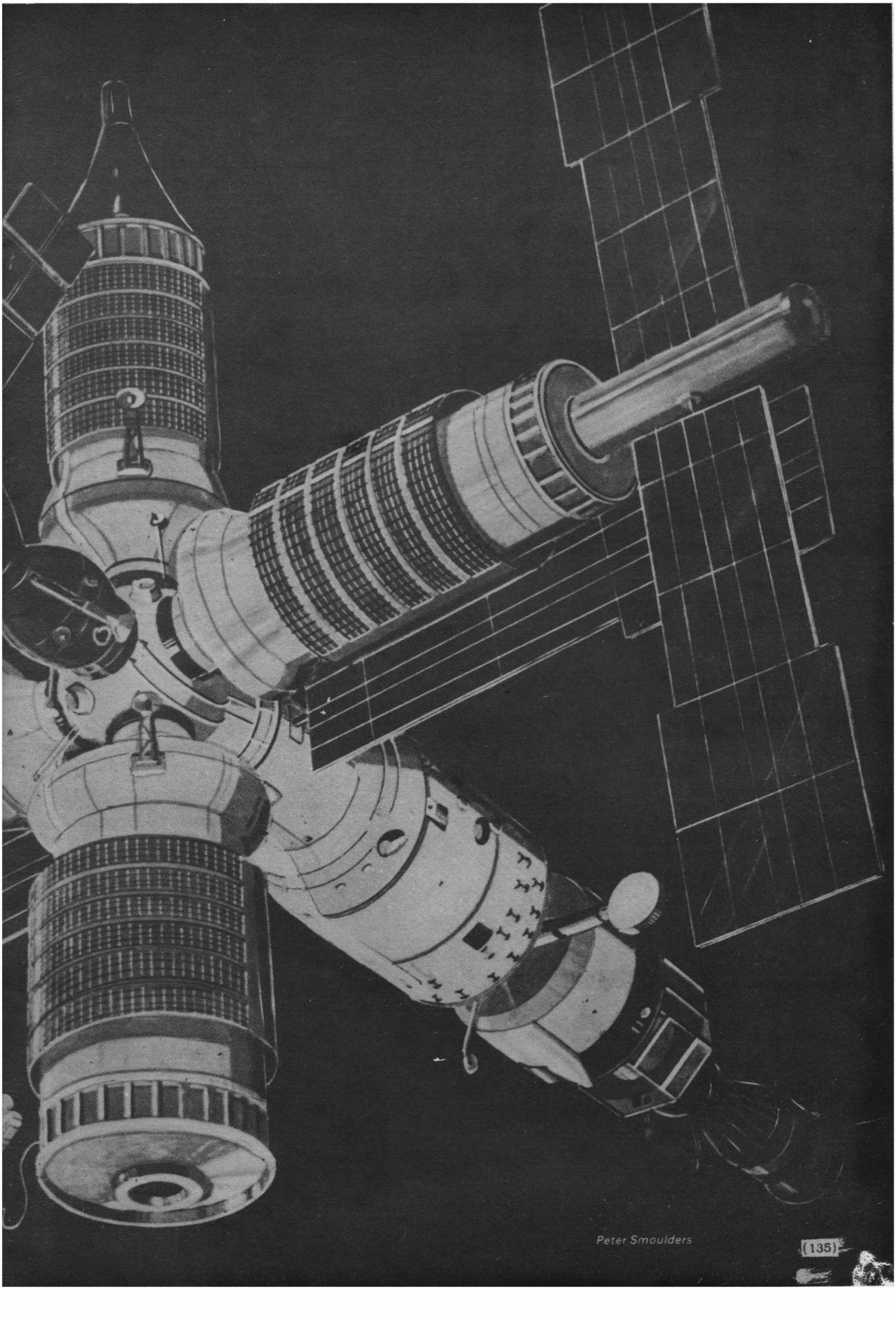
The Soyuz spacecraft has been docked 45 degrees to the X-axis of the core vehicle to achieve maximum clearance of the solar panels. One of the special modules, fitted for materials processing, has a large return capsule to bring space products like alloys and crystals to Earth.

Peter Smolders a Dutch space consultant and writer, based his work on extensive discussions with Soviet space experts. Smolders is the author of "Soviets in Space" (1973) and "Living in Space" (1986).

Mir Basic Data

The Mir Base Unit is 13.13 metres long with a maximum diameter of 4.2 metres and a mass of 21 tonnes. There are six docking units, five of them located on the transfer compartment and one at the rear. The diameter of all the docking unit hatches is 0.8 metres. Two solar panels span 29.73 metres and have a useful area of 76 sq metres.

The two main engines located around the rear docking unit each have a thrust of 300 kgf whilst the 32 smaller reaction control jets located at 90 degree intervals around the Service Propulsion Module each have a thrust of 14 kgf. The station has a pointing accuracy of 1.5 degrees in the rough mode and 15 minutes of arc in the precise mode.



Peter Smoulders

Mir in Action

Yuri Romanenko.

Alexander Laveikin.

Report by Neville Kidger

The Soviets gave unprecedentedly open coverage to their resumption of manned activities at the beginning of the year which began on February 5 with the launch of Soyuz TM-2 with cosmonauts Yuri Romanenko and Aleksander Laveikin, the first crew to man the Mir Base Module in 1987.

Progress 27 in Flight

The 1987 flight activity with Mir began at 0606 (all times GMT unless otherwise stated) on January 16 with the launch of Progress 27 from the Baikonur Cosmodrome. The unmanned cargo spacecraft conducted a two-day rendezvous with the station and docked automatically with the rear port of Mir at 0727 on January 18. The launch and docking were covered live by Soviet television.

Progress 27 delivered some two tonnes of various cargoes to the station. The Soviets said that "soon" the voices of cosmonauts would be heard from the station and that a scientific module called "Roentgen" carrying an astrophysics payload would be launched to dock with the station. This will be the cosmonaut's main place of work.

The astrophysics module had already been announced by the Soviets as being in preparation and that it would carry experiments from Holland, ESA, the FRG and the USSR. The four main experiments are:

- Sirene-2, the ESA high-pressure gas scintillation proportional spectrometer, an improved version of an experiment carried by ESA's EXOSAT spacecraft. It will study X-ray sources in the 2-100 keV range.

- The Dutch experiment is from the Netherlands Space Research Organisation based in Utrecht and features a Coded Mask Imaging Spectrometer called TTM from Birmingham University (the Dutch group integrated the experiment onto the package). TTM is an improved version of an instrument which flew on the Spacelab 2 flight in 1985. The UK group originally expected the experiment to fly on Salyut 7.

- The West German Max Planck Institute and the University of Tubinger are providing a Phoswich scintillation spectrometer which will detect X-ray sources from 15-250 keV.

- The Soviet instrument is a sensor called Pulsar X-1 which will detect X- and gamma ray sources up to 800 keV energies.

Control of the module will be effected from the Flight Control Centre (FCC) by a specially-trained group of Soviet technicians. Observers from the other participating countries will also be at the FCC for the one to two years of the project.

The cosmonauts will align the complex on the celestial targets and the ground will control operation of the scientific experiments. Much of the observing time will be spent observing period variations in X-ray source emissions. There are no plans for the cosmonauts on Mir to service the experiments or repair them in the event of failure.

Soyuz TM-2 in Preparation

On January 28 the Soviets announced that a two-man crew was at the Baikonur Cosmodrome in the final stage of training for their launch on Soyuz TM-2. The cosmonauts were named as Yuri Romanenko and Aleksander Laveikin. Romanenko would be making his third flight but for Laveikin (35), a design engineer from the Morolev Bureau selected as a cosmonaut in 1978, it would be his first mission. The cosmonauts had arrived at the cosmodrome on January 23 and Soviet TV showed pictures of them undergoing medical tests, in their Soyuz TM cabin and relaxing by playing the Soviet version of Pool. The men were interviewed at length about their impressions of each other and the upcoming flight.

Later coverage contained spectacular scenes from inside the MIK assembly building, of the assembly of the Soyuz carrier rocket and the pre-dawn roll out to the launch pad. This TV coverage was also carried by western news organisations.

On February 4 the two men gave a live press conference at which Vladimir Shatalov, head of the cosmonaut training centre, said that both the prime and reserve crews is believed to "prepared for the start of a long space flight". (The reserve crew may be Vladimir Titov and Aleksandr Serebrov).

The cosmonauts said that they were "very satisfied" with their transport spacecraft and had checked some of its systems and stowable equipment. The men had already trained on a mock-up of the astrophysics module which they said would be "launched in a few months time".

The module has been expected by most observers to be of the heavy Cosmos type with a 21 tonne mass but it was reported from the USA that the module is the add-on rear module shown by the Soviets at Star Town and illustrated in ***Spaceflight***, Sept/Oct 1986, p.347. The Soviets announced that the launch of Soyuz TM-2 would occur at 0038 Moscow Time on February 6 (2138 GMT February 5).

Launch of Soyuz TM-2

On February 5 the Soviet radio and TV stations gave wide coverage to preflight activities including live pictures of the men suiting up surrounded by masked, white-overalled technicians. The process took place behind a glass screen to keep infection away from the two cosmonauts. The men gave short interviews before they left the building for the launch pad and the activities were watched by the two Soviet/Syrian crews.

The launch itself was shown live during a 25 minute broadcast on Soviet TV which started at 0025 Moscow Time. At the time of launch, 2138, the Mir station was over the cosmodrome. The approach was to take two days, the Soviets said, in order to save fuel on Mir. On the Salyut stations docking was accomplished by the Salyut facing the oncoming Soyuz. However, as the mass of the Mir complex increases by 21 tonnes each time a module is added, the capability to manoeuvre the complex will be reduced. The Soyuz TM spacecraft, with its improved "Kurs" system allows the Soyuz to fly around the station and dock with the front or rear port regardless of the orientation of the complex.

During the first day of flight the cosmonauts checked the systems of the Soyuz TM in manned flight for the first time. Several orbital manoeuvres were conducted in order to place the spacecraft onto the correct approach trajectory for the docking which the Soviets said would occur early in the morning of February 8, Moscow Time.

Back to Mir

The docking operation began at a

separation distance of 180 km with firings of the Soyuz TM-2 engine. The "Kurs" system ensured that the Soyuz approached the Mir station correctly and TV pictures, broadcast the next morning on Soviet TV, showed the final stages of approach. During the night-time passes the cosmonauts saw the lights of the station. The docking took place over northern China and first contact was made at 2327:40 on February 7. Because the event occurred during the early hours of February 8 Moscow Time there was no live TV coverage but radio did cover the docking and the transfer live.

Ninety minutes after the docking the FCC gave the cosmonauts permission to open the hatches into the station. Leonid Kizim and Vladimir Solovyov, who vacated the station on July 16, 1986 had left a TV camera pointing to the forward hatch and this beamed colour pictures of Romanenko opening the hatch and waving cheerfully at the camera. He then floated into the station with Laveikin.

TASS reported that the flight would be a new stage in the working of Mir and that plans now involved development of "a permanent orbital manned complex with specialised research and utility modules".

Romanenko was soon involved in a technical discussion with the deputy leader of the mission, cosmonaut Vladimir Solovyov.

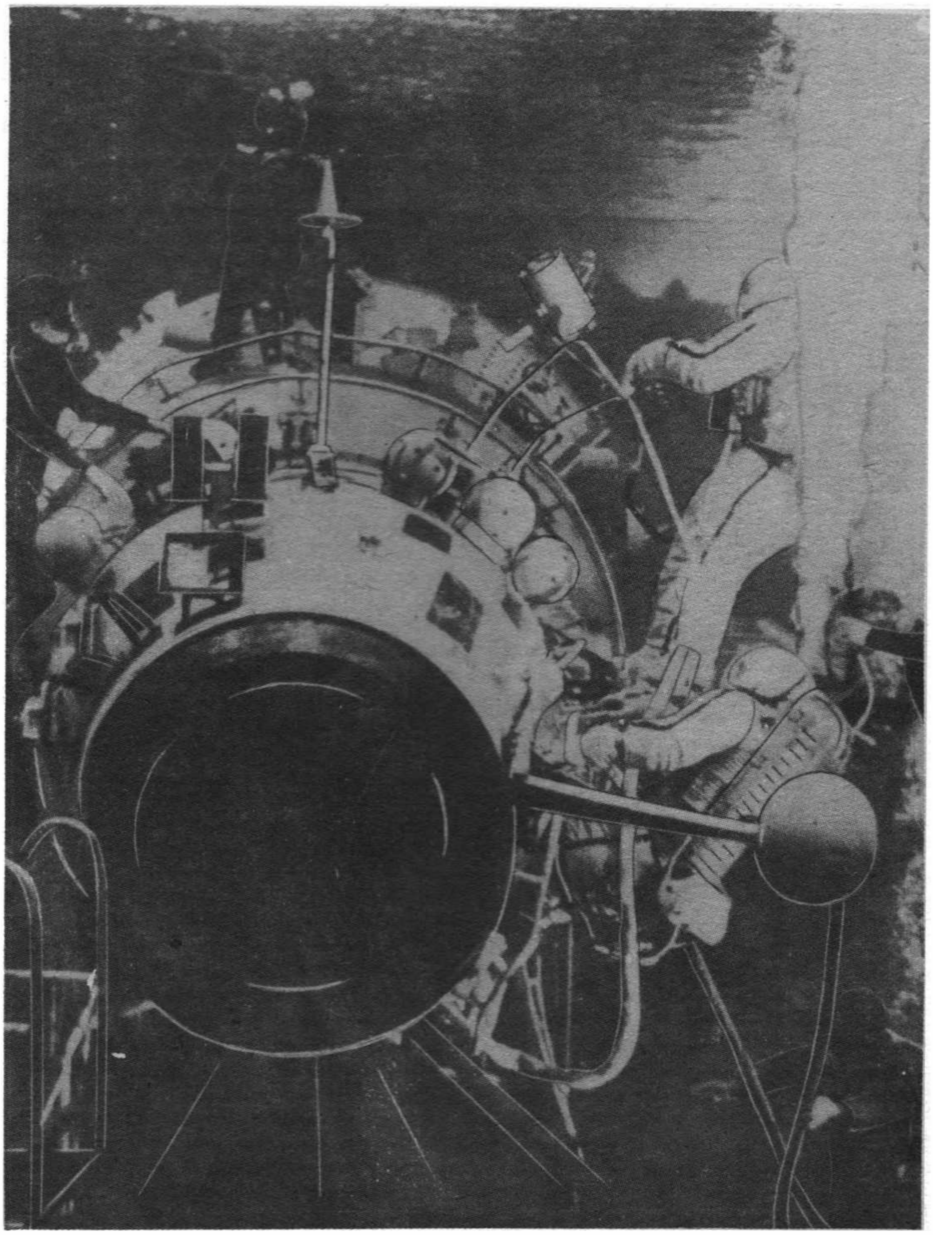
The first tasks involved the activation of the temperature control system to "a new operational mode", switching on of the water regeneration system, and checking the preformance of instruments and units. The first medical tests were conducted on February 8.

On February 9 it was reported that the complex was in an orbit of 369 x 328 kilometres with a period of 91.4 minutes and an inclination of 51.6 degrees. The crew continued demothballing the systems of the station.

By the next day the cosmonauts were reported to have passed the critical period of "adaptation" to weightlessness and had shifted their sleep pattern to normal, working to Moscow Time. Unloading the Progress 27 cargo spacecraft began and continued over the next few days.

On February 11 the orbit of the complex was adjusted by means of the Progress 27 spacecraft's engines.

The cosmonauts maintained communications with the ground via the ground-based tracking stations and the tracking ships on the high seas used by the Salyut series of stations. It was reported that the Cosmos 1700 "Luch" relay spacecraft in geostationary orbit had failed and had drifted off-station. The Soviets have announced plans for a three-satellite network in geostationary orbit to relay signals from the Mir complex to the FCC and the first satellite of the system was identified as "Luch". The system may also be behind again in deployment following the loss of the payload launched on a Proton from Baikonur on January 30. That satellite was stranded in a short-lived low orbit shortly after launch due to a failure of the "Block-D" upper stage of the Proton. The loss has yet to be reported by the Soviet authorities who gave the satellite a Cosmos designation.



Cosmonauts undergoing extravehicular activity (EVA) training in a neutral buoyancy water tank. One of the first EVA's for Romanenko and Laveikin may involve deployment of a third solar panel for the Mir base module. *Novosti*

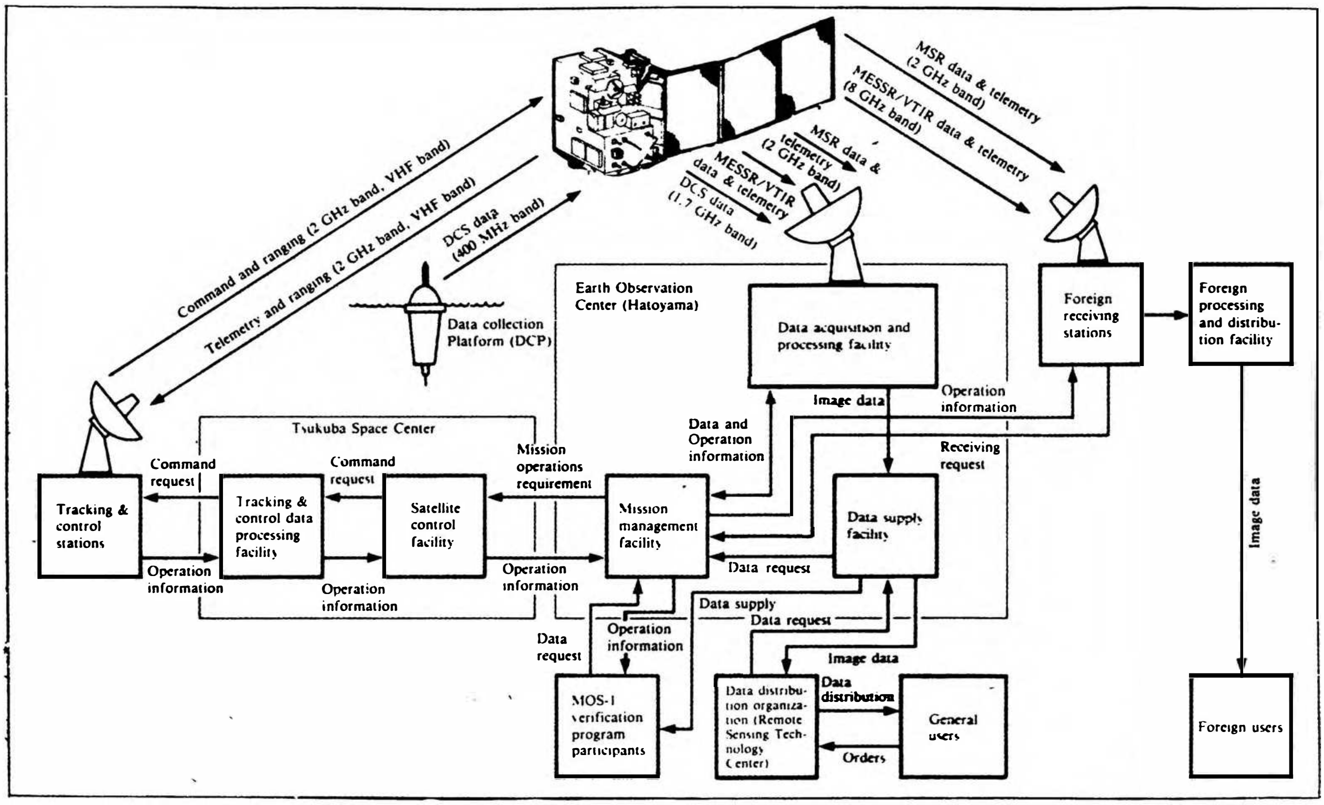
Syrian Flight

The first visitors to Romaneko and Laveikin will be the joint Soviet/Syrian crew and details of this flight were announced at a press conference in Moscow on December 18, 1986. The prime crew members are Lt. Col. Aleksandr Viktorenko (Commander) Aleksandr Aleksandrov (Flight Engineer) and Syrian Muhammad Faris (Research Engineer). Viktorenko, born in 1947, was selected as a cosmonaut in the 1970 intake and has been commander of reserve crews for Salyut 7 and Mir missions.

The reserve crew for the "Syrian" mission consists of Lt. Col. Anatoli Solovyov (Commander) Viktor Savinykh (Flight Engineer) and Syrian Research Engineer Munir Habib. Solovyov, born in 1948, was selected in the 1976 cosmonaut intake.

The Soviet Flight Engineers (prime and back-up) are both experienced cosmonauts with long orbital missions behind them.

The flight is scheduled to start at 0230 GMT on July 22 and the Soyuz TM spacecraft will dock with Mir during the third day of flight. The three-man crew are due to return to Earth at 2230 GMT on July 29. The flight times are unusual because they are well outside the limits normally imposed on Soyuz activities by the need to land at specific times near to sunset in Kazakhstan.

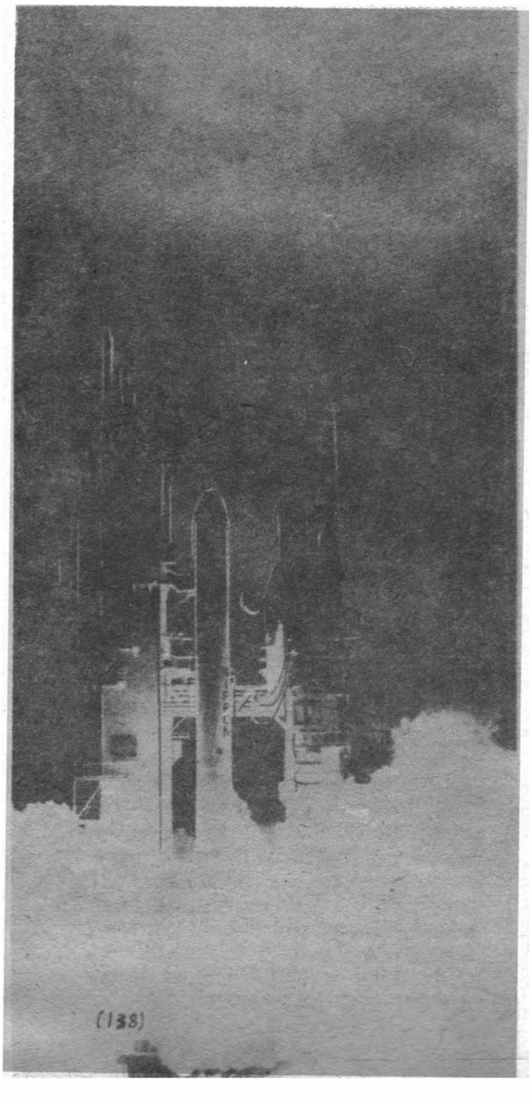


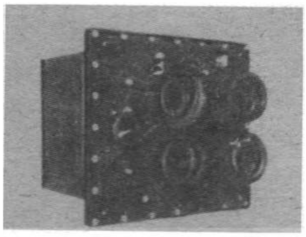
MOS-1 operating system.

Pictures: NASDA.

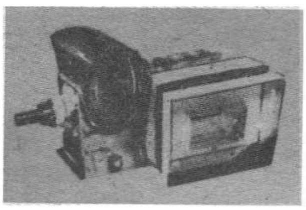
Marine Observation Satellite

N-II launch of MOS-1

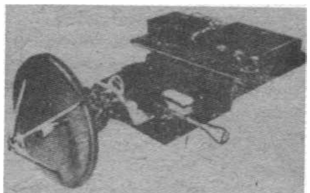




The Multi-Spectrum Electronic Self-Scanning Radiometer (MESSR) which gathers data from both land and sea.

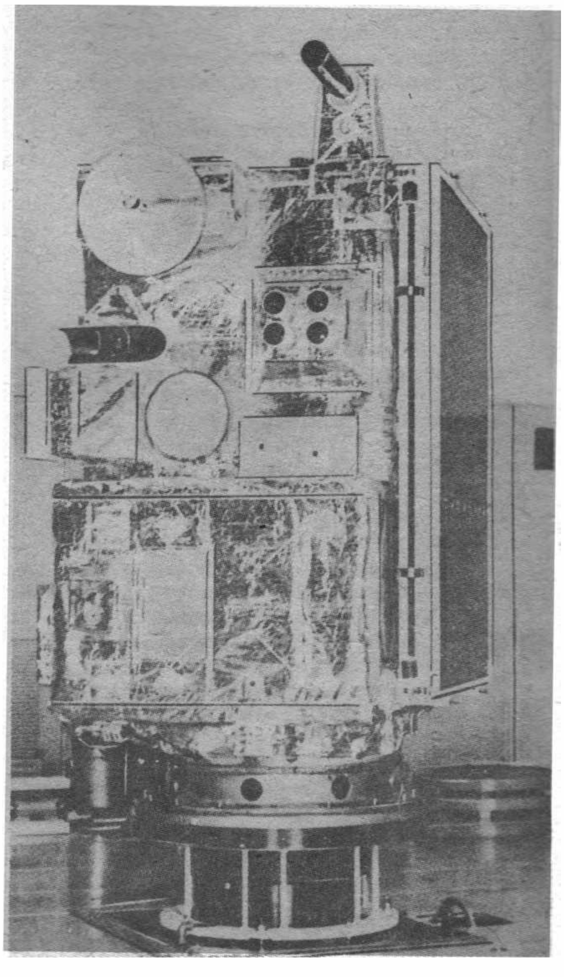


Visible and Thermal Infrared Radiometer (VTIR) for collecting information on clouds, water surface temperatures, etc.



Microwave Scanning Radiometer (MSR) for gathering data on sea ice, snowfall, water vapour content at the ocean surface and in the atmosphere.

MOS-1 with solar panel (right) folded.



OCEAN SATELLITE OPENS REMOTE SENSING ERA

Japan's New Space Bid

Japan launched its first Earth resources mission on February 19 at 10:23 (JST) from the Tanegashima Space Centre using the N-II version of its Delta-based launch vehicle. It marked the first stage of a project that will lead to more advanced remote sensing satellites in coming years.

Lift-off of MOS-1 (Marine Observation Satellite) was the second launch in a period of just over two weeks for the Japanese. MOS-1, renamed MOMO-1 (peach blossom) in accordance with Japanese tradition after reaching orbit, followed closely the launch of the X-ray astronomy satellite Astro-C (Ginga) on February 4 (*Spaceflight*, March 1987, p.95) for which the UK supplied part of the payload.

Earth Observation

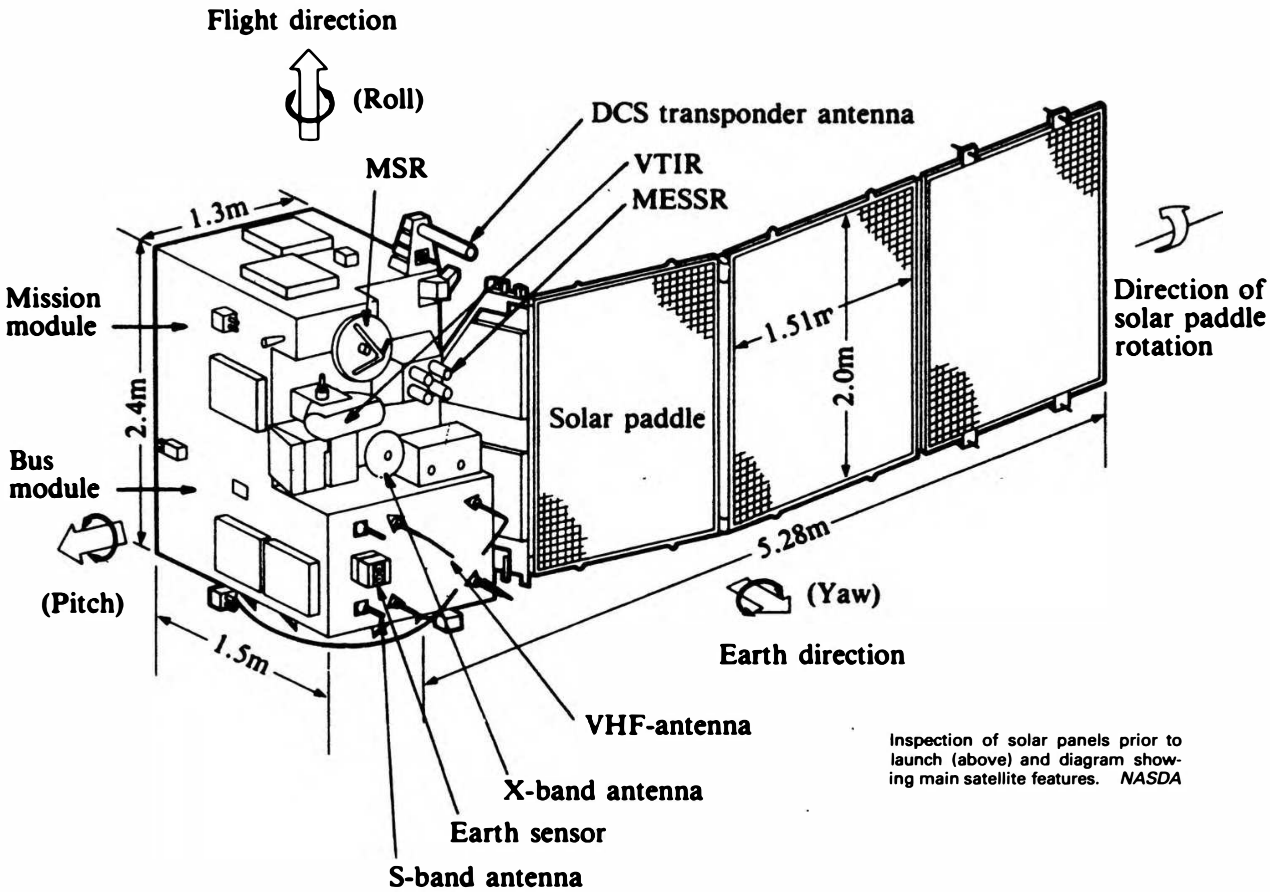
Artificial satellites that use remote sensing systems for periodic observation of wide areas of the Earth's surface are now assuming an important role as tools for exploring and utilising Earth resources, as well as preserving the Earth's environment. Earth-observation satellites now in service include the NOAA and Landsat series of the United States and the French Spot.

In Japan, the National Space Development Agency (NASDA) has assumed a role in the Earth-observation satellite programme by undertaking development of Japan's first such experimental satellite system, the Marine Observation Satellite 1 (MOS-1).

MOS-1 is intended to establish fundamental technologies for Earth-observation satellites, primarily by observing phenomena such as ocean colour and temperature. In addition to oceanographic studies, the satellite's observations are expected to be of value to agriculture, forestry, fishery and environmental preservation.

Mission objectives of MOS-1 are:

- Development of observation sensors; verification of their functions and performance, and experimental observation of the Earth (in particular the oceans)



Inspection of solar panels prior to launch (above) and diagram showing main satellite features. *NASDA*

using such sensors.

- Basic experiments on a data collection system (DCS).
- Establishment of fundamental technologies for Earth observation satellites.

It is also designed to evaluate techniques for placing satellites into Sun-synchronous orbit; tracking and control techniques for satellites in Sun-synchronous orbits, and techniques for operating Earth observation satellites.

MOS-1 is made up ot two rectangular parallelepipeds: a bus module and a mission module. The latter carries the data collection system (DCVS) and three Earth observation radiometers:

- A multi-spectrum electronic self-scanning radiometer (MESSR).
- A visible and thermal infrared radiometer (VTIR).
- A microwave scanning radiometer (MSR).

Conceptual design of MOS-1 and partial model tests of sensors began in 1977 with full-scale development starting two years later.

Contractors for the satellite system were: NEC (prime), Mitsibishi (attitude control), Toshiba (solar panel), Tshikawjima-Harima (attitude control gasjet system). The sensors were built by: NEC (MESSR), Fujistu (VTIR) and Mitsibishi (MSR).

The three sensors are all passive radiometers which detect reflected solar rays or radiated electromagnetic waves from the Earth's surface.

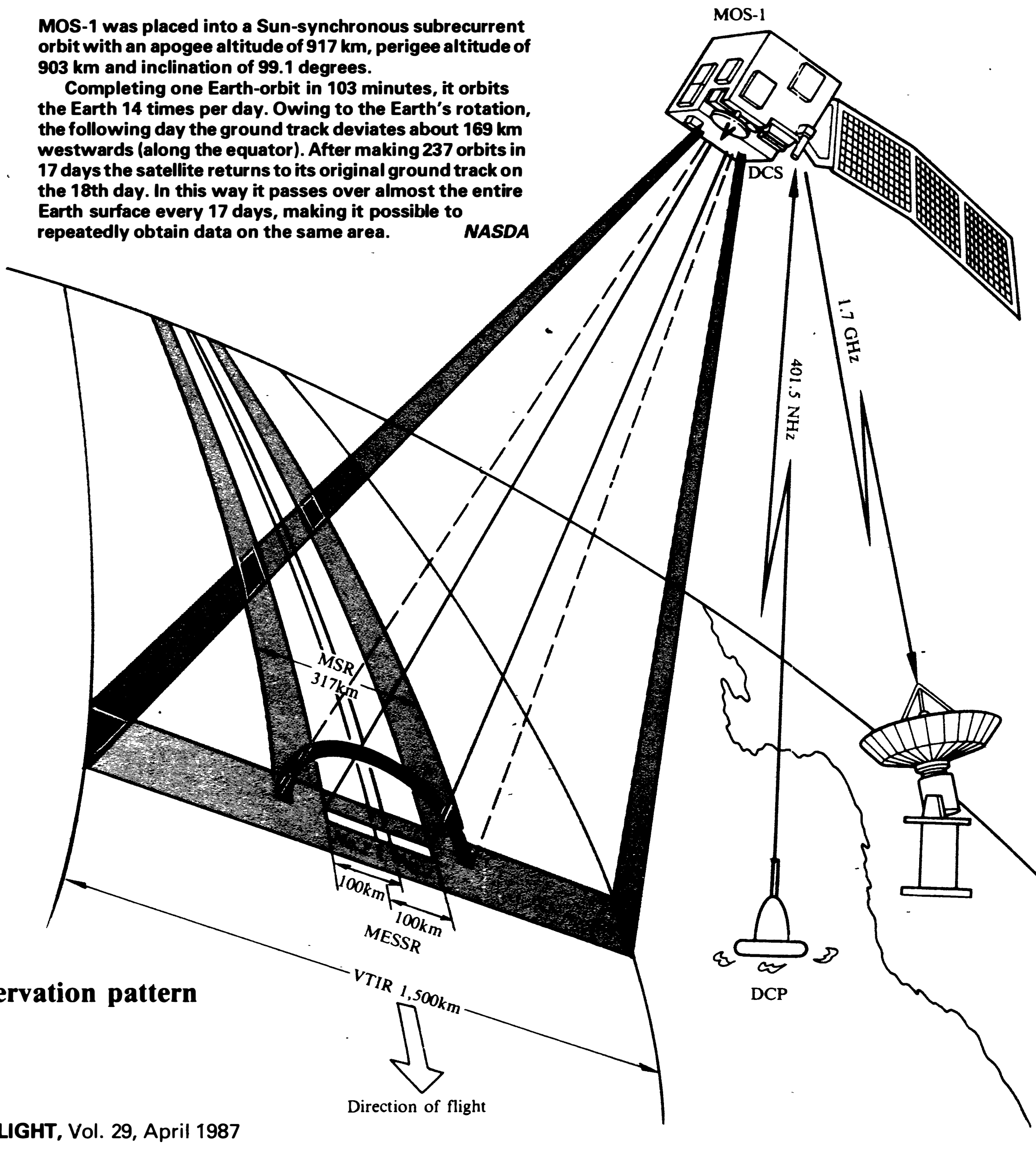
The MESSR will monitor sea surface colours and provide information on land surfaces in the visible and near-infrared ranges; the VTIR will make wide-area observations of the Earth's surface in the visible and thermal infrared ranges to provide information on the distribution of atmospheric water vapour and surface temperature; and the MSR will survey quantities of vapour, snow and ice by monitoring microwave radiation from the surface at two frequencies.

The MESSR will continuously acquire data on a zone with a width of either 100 km (with one system) or 185 km (with two systems) perpendicular to the direction of the satellite's flight. The VTIR and MSR will obtain data from zone widths of about 1500 km and 317 km, respectively. Acquired data will be transmitted to the Earth in real time.

MOS-1 is also equipped with a DCS for relaying data acquired by data collection platforms on the ground to other ground-based stations.

Processed data will subsequently be offered to general users for a fee by the Remote Sensing Technology Centre (RESTEC) and NASDA will also accept foreign requests for direct reception of data from MOS-1.

A second MOS craft will be launched by the end of the decade followed in the early 1990's by Japan's advanced Earth Resources Satellite (ERS).



MOS-1 was placed into a Sun-synchronous subrecurrent orbit with an apogee altitude of 917 km, perigee altitude of 903 km and inclination of 99.1 degrees.

Completing one Earth-orbit in 103 minutes, it orbits the Earth 14 times per day. Owing to the Earth's rotation, the following day the ground track deviates about 169 km westwards (along the equator). After making 237 orbits in 17 days the satellite returns to its original ground track on the 18th day. In this way it passes over almost the entire Earth surface every 17 days, making it possible to repeatedly obtain data on the same area. ***NASDA***

Observation pattern

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Future UK Space Participation

Manned or unmanned factories in space, complex orbital stations serving as laboratories, observation posts or service stations and of course the vehicles necessary for their construction and supply will be part of the scenery in space in the 1990's. European industry is preparing for the 21st century.

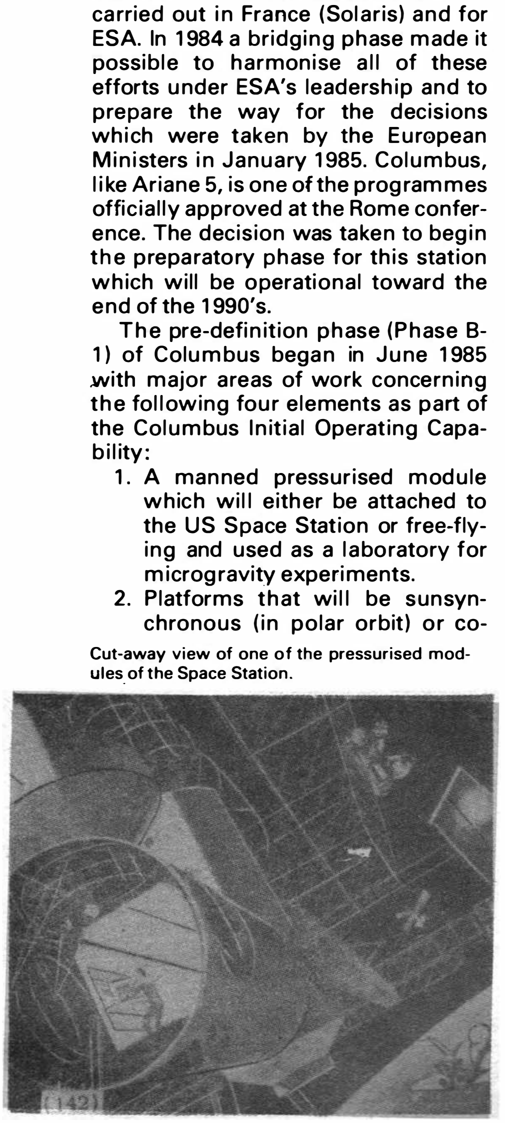
Columbus, the European Orbital Station, will be developed by the European Space Agency (ESA) as Europe's contribution to NASA's large manned station. Columbus is also a first step towards an independent European space station.

Studies for Columbus began in W.Germany at MBB-ERNO and in Italy at Aeritalia Space Systems Group as a Spacelab follow-on programme around 1982. Similar studies were also carried out in France (Solaris) and for ESA. In 1984 a bridging phase made it possible to harmonise all of these efforts under ESA's leadership and to prepare the way for the decisions which were taken by the European Ministers in January 1985. Columbus, like Ariane 5, is one of the programmes officially approved at the Rome conference. The decision was taken to begin the preparatory phase for this station which will be operational toward the end of the 1990's.

The pre-definition phase (Phase B-1) of Columbus began in June 1985 with major areas of work concerning the following four elements as part of the Columbus Initial Operating Capability:

1. A manned pressurised module which will either be attached to the US Space Station or free-flying and used as a laboratory for microgravity experiments.
2. Platforms that will be sunsynchronous (in polar orbit) or co-orbiting.
3. A resource module for providing power supply, thermal control, attitude control, and life support to allow the pressurised module to be detached from the main space station (Core Station) and operate as a man-tended free-flyer.
4. A service vehicle, being a kind of 'tug' which may or may not be manned.

Cut-away view of one of the pressurised modules of the Space Station.



COLUMBUS SPACE STATION HIGHLIGHTED

ESA awarded pre-definition study contracts to European industry as follows: MBB-ERNO, system contractor; Aeritalia, pressurised module(s); British Aerospace, platform(s); Dornier, resource module; Aerospatiale, service vehicle.

The UK agreed to participate in studies of all Space Station elements but on condition that the industrial leadership of the Polar Platform would be awarded to a British company. Preliminary analysis had identified the Polar Platform as an element of particular UK interest, being the one for which the largest potential user community existed in the UK and the one which offered the best medium-term economic prospects.

During Phase B (project definition) studies, the elements of the Columbus Programme have been re-defined by agreement. Those now being studied are:

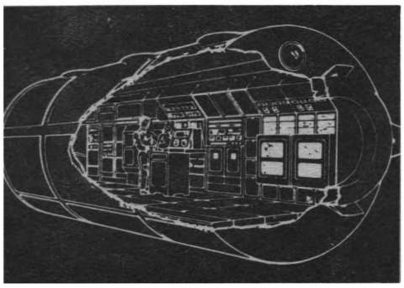
1. A manned Pressurised Module that would remain permanently attached to the manned Core Station.
2. A Polar Platform.
3. A Man-Tended Free-Flyer consisting of a Resource Module attached to a second smaller Pressurised Module.
4. Enhancements of the small retrievable platform Eureca, as a partial response to the need for Co-orbiting Platforms.

In 1985, a study was set up by the Department of Trade and Industry to consider how the UK might utilise, and exploit in the national interest, the European participation in the US Space Station through the Columbus Programme. The study subsequently became the responsibilty of the British National Space Centre (BNSC). At the end of 1986 the study was published in eleven volumes entitled, 'Columbus/Space Station, United Kingdom Utilisation Study 1985/86'. Volumes I and II provide The Executive Summary and The Main Text, while Volumes III to VII are concerned with different sciences and their applications namely Atmospheric, Oceanic, Land, Polar and Microgravity. Volumes VIII to XI deal with Astronomy, Solar Terrestrial Physics, Data and Operations, and The Remote Sensing Value-Added Industry.

The report is the result of study, consultation and discussion involving about 300 people – scientists, engineers, businessmen and some interested members of the public. Its objective has been to define and assess opportunities which participation in the Space Station and Columbus Programmes might provide for the potential UK user community and to recommend strategies for participation, and for exploiting these opportunities.

The study confirmed the existence of an extensive British community engaged in commercial, operational and scientific applications of space, which by the beginning of the Space Station era will inevitably have greatly expanded, both in size and range of applications, and be making correspondingly greater demands for spaceflight opportunities. The Columbus programme is seen as an effective means of gaining such opportunities. Industrialists believe that participation in Columbus will enable British industry to develop, and significantly expand, its capabilities and markets,

INTERNATIONAL SPACE REPORT


Columbus pressurised module.

and that without participation it will become increasingly difficult to compete in high technology in world markets.

The study recommends that the UK should retain industrial leadership of the Polar Platform and devote to it at least 60 per cent of the industrial expenditure from its contribution to the Columbus Programme. It also recommended that Britain should be involved in five major areas of work: the space segment of the Columbus infrastructure, advanced sensor payloads, a national ground segment, underpinning research and development, and the establishment of a stronger user community.

Concerning astronaut activities related to the Space Station, the study recommends vigorous British participation and that a contribution be made to European facilities for the screening and training of astronauts. Other recommendations are for UK participation in the Columbus Ground Segment on British soil and for the development of Columbus payloads in the Earth Observation, Science and Microgravity Programmes of ESA and BNSC.

Whereas UK participation in some ESA projects, such as the Ariane launch vehicle, has been minimal, the recommendation for Columbus is for a full commitment at a level appropriate to that of the UK's GNP relative to the GNPs of other European countries.

Young Calls for New Tests on Shuttle Booster

Astronaut John Young has made known his doubts that a faulty booster was the sole cause of the loss of the Shuttle Challenger. High vertical wind shear and a failed attachment ring are cited as factors likely to have contributed to the ultimate rupture in the booster joint.

His report is now under consideration by NASA's new Office of Safety and recommends that currently planned ground tests of the re-designed booster should be extended to simulate the worst cases of wind shear and bending loads that could occur.

ZERO-G MEDICAL RESEARCH

The first in a series of experiments aimed at improving a revolutionary treatment for diabetes was performed in February by Canadian astronauts on board a NASA jet used to simulate the near-zero gravity environment of space.

The experiment, developed by Canadian Astronautics Limited of Ottawa and funded by the National Research Council of Canada, was designed to assess the effects of microgravity on a new technique for encapsulating living insulin-producing cells for implantation in diabetics.

This microencapsulation technique, developed in Canada by Connaught Laboratories Limited of Toronto, could ultimately free millions of diabetics of the need for daily insulin injections. Laboratory experiments so far have shown that injection of insulin-producing cells contained in microscopic capsules has controlled the symptoms of diabetes in animals for up to one year.

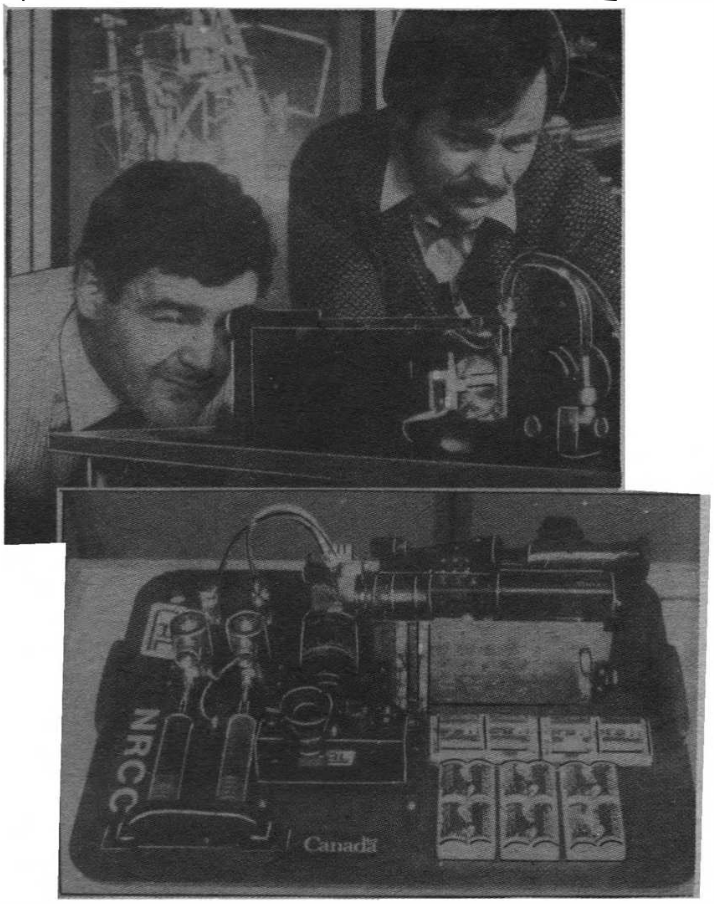
The membranes of these microcapsules, which protect the insulin-producing cells from attack by the body's immune system, act like miniature sieves. Glucose in the bloodstream passes freely through the membrane into the microcapsule and triggers insulin production, while insulin produced by the cells inside the capsule flows out into the diabetic's body.

Earth-based experiments by Connaught indicates the smoother, more spherical the capsules, the longer they survive in the body, and hence the interest in making the capsules in space, where the virtual absence of gravity allows the formation of near-perfect spheres.

The first experiment was carried out over a three-day period of NASA's KC-135 jet flown from Houston. Canadian astronauts Steve MacLean, Bjarni Tryggvason and Bob Thirsk, activated and monitored it during 50 parabolic trajectories where weightlessness is experienced in 20-second bursts.

Researchers are now analysing images taken by still and video cameras to study the effect of microgravity on the formation of concentric droplets with differently-shaped injectors. This will lead to the design of an optimum cell encapsulation injector. Future tests will use live insulin-producing cells and actual materials for cell encapsulation.

Canadian astronauts Marc Garneau (left) and Bjarni Tryggvason with the cell encapsulation experiment which is being used in a series of tests on NASA's KC-135 aircraft. *CAI*



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Date of Issue	*Subject*	**Editor**
August 1982	Orbital Dynamics	Dr. D.G. King-Hele
January 1983	Infra-Red Astronomical Satellite	Dr. R. Holdaway
July 1984	Space Science at Rutherford Appleton Laboratory	Dr. R. Holdaway
August 1984	Solar System Exploration (at Jet Propulsion Laboratory and in the US)	Dr. K.T. Nock
October 1985	Mission Systems, Jet Propulsion Laboratory	Dr. W.I. McLaughlin
May 1986	Space Science at Rutherford Appleton Laboratory	Dr. R. Holdaway
October 1986	US Opportunities in Space	Dr. D. Baker
December 1986	Remote Sensing, Bristol University	Dr. E. C. Barrett
April 1987	Space Science, Birmingham University	Dr. J. K. Davies

PUBLISHED MONTHLY IN LONDON

Delta Puts Weather Satellite in Orbit

Philip Chien *reports from Kennedy Space Center, Florida.*

NASA successfully launched Delta 179 on February 26, 1987. The payload was the GOES-H Weather satellite, identical to the GOES-G which was destroyed when a similar Delta failed last May. Launch occurred under cloudy skies at 6:05 EST with five VIP guests, the members of the STS-26 flight crew, who were at the Kennedy Space Center for a visit.

The launch was originally scheduled for two days earlier, on February 24. However there was a small leak in a first stage fuel valve, similar to a leak which delayed the Delta launch last May and another day was lost due to high level winds above Florida's east coast.

The ensuing flight was without incident, other than a slightly low performance from the third stage and an early firing of tha Apogee Kick Motor (AKM). Normally spacecraft engineers fire the AKM on the second day of flight following a day of vehicle checkout but spacecraft engineers decided to fire the AKM early after it was determined that there were problems with the AKM heaters. Even with the problems GOES was placed in a nominal orbit and was expected to be in operation within a month.

GOES will be positioned over Columbia at 75 degrees West longitude, to observe weather formations over the Eastern United States and Atlantic Ocean. After a month of checkouts, NASA will turn GOES over to NOAA (National Oceanic and Atmospheric Administration) for use as GOES East. The present GOES in orbit will be positioned at 135 degrees West longitude for Western US and Pacific ocean pictures.

Besides the weather tracking functions, GOES-H also carries an experimental 406 MHz SARSAT (Search and Rescue SATellite) system. SARSAT, an international project involving the US, USSR, UK, Canada, Norway, and other nations, has been credited with saving over 500 lives after plane crashes, shipwrecks and even a race car driver in an accident (***Spaceflight***, February 1987, p.87). All US aircraft and many worldwide aircraft are required to carry rescue transponders. The operational US 121.5 MHz SARSAT receivers are aboard TIROS low polar orbit weather satellites and USSR receivers are aboard Cosmos navigation satellites. The GOES SARSAT is the first receiver to operate in Clarke orbit and the first to operate at the higher 406 MHz frequency.

NOAA normally needs three GOES in orbit at any given moment, one to cover each coast of the Western hemisphere and a backup in case anything goes wrong with an operational craft. Since July 1984, when a filament burned out on GOES-E (the space equivalent of a burnt out light bulb), NOAA has been operating with only one craft, GOES-F. That craft has been moved between the eastern and western orbital positions to cover eastern hurricane and western storm seasons, using up the valuable onboard fuel reserves.

GOES-G would have restored the two craft system, with GOES-H as the in-orbit back-up, but it was destroyed in the Delta accident. GOES-H will restore the two satellite system but it will be at least another two years before another GOES can be launched. GOES-H is the last of the advanced GOES series produced by Hughes Aircraft. The next generation of more powerful, heavier spacecraft GOES-Next, will be produced by Ford Aerospace. GOES-I is now scheduled for launch by an expendable rocket in 1989 after being transferred from the Shuttle (***Spaceflight***, March 1987, p.97).

The launch of Delta 179 also marked the first time in over three years an expendable rocket has been launched by the US while another rocket undergoes preparation on an adjacent pad. GOES-H was launched from Pad 17A, while Delta 182, with Palapa B2 undergoes checkout on Pad 17B. Palapa, an Indonesian communications satellite, was scheduled for launch no earlier than March 19. The last occasion two expendables were undergoing checkout at the same time was in 1983, when Delta 170 with Galaxy A and Delta 171 with Telstar 301 were launched on June 28 and July 28 respectively. By coincidence the Palapa B1 satellite was launched the week before Galaxy A, from Challenger aboard the STS-7 mission. Under the present schedule two rockets won't be prepared simultaneously on adjacent pads for at least another two years.

Besides GOES-H and Palapa B2, a FltSâtcom satellite was undergoing checkout for a March 26 launch aboard an Atlas Centaur rocket. The practice countdown for the FltSatcom mission was held February 27, the day after the GOES-H launch, and the practice countdown for the Palapa mission the following day. The three launches scheduled within a month formed NASA's busiest launch schedule since the Challenger accident.

Palapa is the first communications satellite originally scheduled for launch aboard the Shuttle which has been rescheduled and transfered to an expendable booster. It was originally planned for launch on Shuttle flight 61H with the Westar VI-S, and Skynet IVA comsats from Columbia, in the summer of 1986.

Members of the STS-26 crew who were at the Cape to see the Delta launch of the GOES-G weather satellite. They are (from left): Mission Specialists David C. Hilmers, George D. "Pinky" Nelson and John M. Lounge, Pilot Richard O. Covey, and Commander Frederick H. Hauck.

SATELLITE DIGEST – 201

Robert D. Christy

Continued from the March 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1803, 1986-94A, 17177.
Launched: 0705, 2 December 1986 from Plesetsk by A-2 or F2.
Spacecraft data: Not available, but it may be similar to the navigation satellites in which case it has cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Probably a geodetic satellite.
Orbit: 1498 x 1503 km, 116.05 min, 82.61 deg.

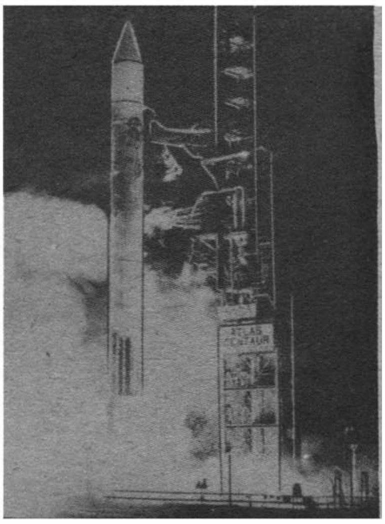
COSMOS 1804, 1986-95A, 17179.
Launched: 1010, 4 December 1986 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass in between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 347 x 415 kilometres, 92.20 min, 70.00 deg.

USA 20 (Fltsatcom 7), 1986-96A, 17181.
Launched: 0235, 5 December 1986 from Cape Canaveral Air Force Station by Atlas Centaur.
Spacecraft data: Hexagonal prism, 1.27 m long, and 2.3 m diameter. The mass (excluding fuel) is about 1000 kg. Power is provided by a two-panel solar array set at right angles to the sides of the main body. The Earth-pointing end of the satellite carries a large dish aerial. Three-axis stabilisation is by a combination of momentum wheels and gas thrusters.
Mission: US military communications.
Orbit: Geosynchronous above 179 deg west.

COSMOS 1805, 1986-97A, 17191.
Launched: 0731, 10 December 1986 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1400 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 636 x 660 km, 97.75 min, 82.61 deg.

COSMOS 1806, 1986-98A, 17213
Launched: 1830, 12 December 1986 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 618 x 39287 km, 708.70 min, 62.85 deg, then raised to 619 x 39730 km, 717.65 min, 62.86 deg to ensure daily repeats of the ground track.

COSMOS 1807, 1986-99A, 17217.
Launched: 1400, 16 December 1986 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance, re-entered after 38 days.
Orbit: 169 x 337 km, 89.59 min, 67.14 deg, manoeuvrable.

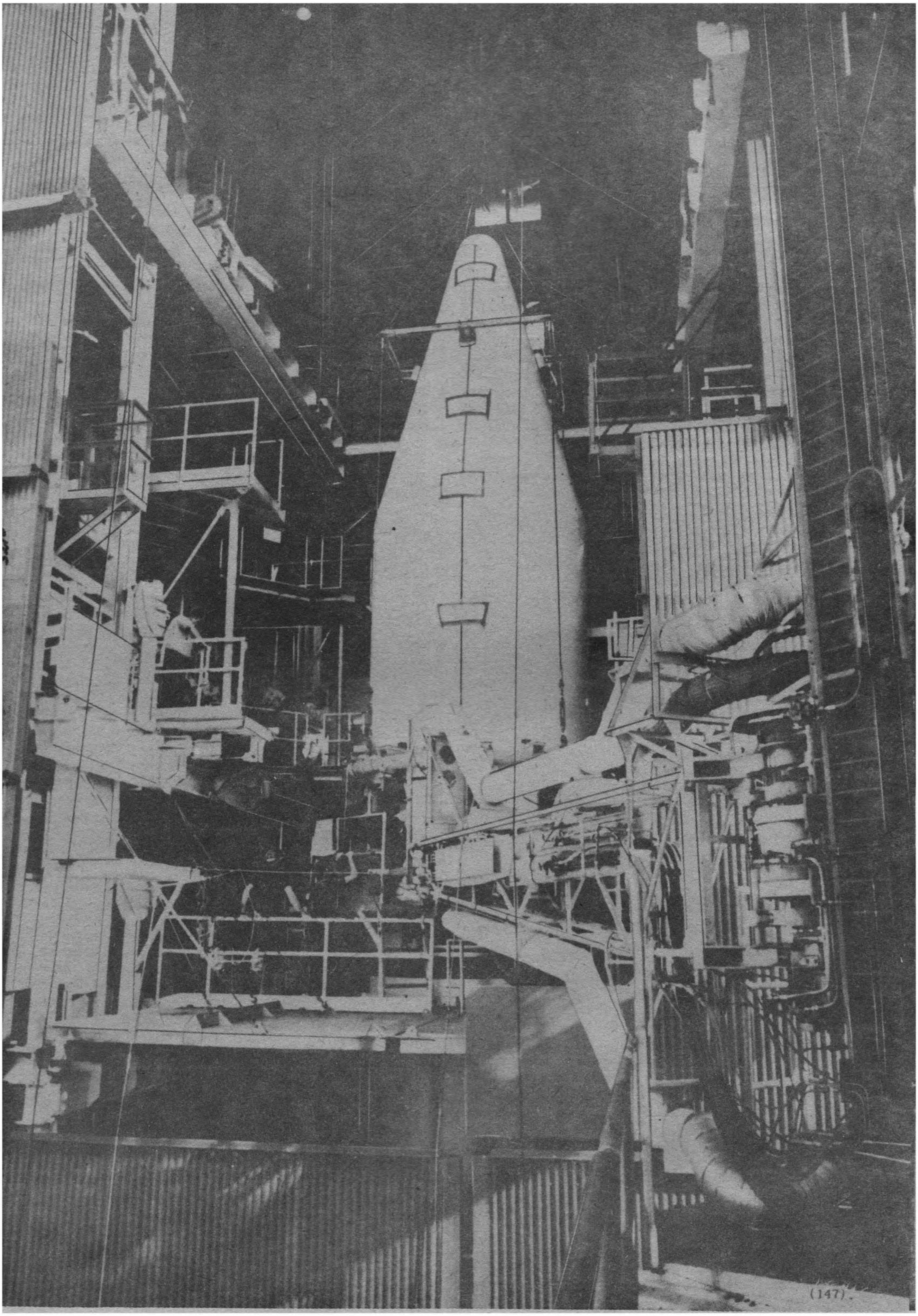


COSMOS 1808, 1986-100A, 17239.
Launched: 1703, 17 December 1986 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 973 x 1020 km, 105.11 min, 82.94 deg.

COSMOS 1809, 1986-101A, 17241.
Launched: 0800, 18 December 1986 from Plesetsk by A-2 or F-2.
Spacecraft data: Not available, but possibly similar to the navigation satellites in which case it has a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Scientific satellite with a package of instruments measuring ionospheric radio-propagation.
Orbit: 945 x 965 km, 104.22 min, 82.53 min.

UPDATES:
1974-81A, MOLNIYA-1 (28) decayed on 29 December 1985 after 4084 days.
1975-9A, MOLNIYA-2 (12) decayed on 4 July 1985 after 3801 days.
1975-125A, MOLNIYA-3 (4) decayed on 12 August 1986 after 3881 days.

The sixth Fleet Satellite Communications (FltSatcom 7) spacecraft is successfully launched from Cape Canaveral (left) to join the system that provides the US Navy and other DoD agencies with instantaneous, UHF communications capability around the world. The colour picture opposite provides a detailed prelaunch view of satellite integration with the Delta booster *NASA*



(147).

A Builder of Spacecraft

Interplanetary spacecraft are the rare birds of the Solar System; Voyagers 1 and 2 were the last JPL spacecraft to be launched (in 1977) and not many others of this breed have followed. Consequently, the skills to design and develop these long-distance machines are not widely known. Ronald Draper, the Development Project Manager for the proposed Comet Rendezvous Asteroid Flyby (CRAF) mission, has been involved in this trade since 1961, along with a few other skilled individuals.

Draper began his work at the Laboratory on Mariner 2, the first successful interplanetary spacecraft, which flew by Venus in 1962. Originally, the spacecraft for the mission was conceived to be quite large, but the Centaur launch vehicle was behind its development schedule; so, the less powerful Atlas/Agena B had to be substituted for the Atlas/Centaur, and the allowed spacecraft mass had to be drastically reduced. The mass at launch was 447 lb, of which 41 lb were devoted to the scientific experiments.

This situation was not atypical because, as Draper comments, spacecraft design is bounded by the triad of launch-vehicle capability, science requirements and desires, and cost and schedule – a lexicon of constraint which has held true to the present day – although cost was less a factor in the very early days of interplanetary exploration when national prestige was felt to be more involved.

Mariner 3 was a great disappointment. Designed to go to Mars, the shroud did not come off after launch, and the mission failed. In ten days, JPL and the famed "skunk works" at Lockheed designed a new shroud for Mariner 4.

Though his efforts on Mariner 3 did not come to fruition, Draper had also served with the Mariner 4 team from conception, through spacecraft development and testing, and gained flight experience on the Spacecraft Performance Analysis and Command (SPAC) Team. The mission was a resounding success and revealed, surprisingly, the presence of craters on the Red Planet.

Mariner 5 represented a return to Venus. Basically, the Mariner 4 spacecraft was converted to make it serviceable in the Venusian environment. The principal change involved the solar panels, which were reconfigured to accommodate the different power and thermal conditions nearer the Sun. In addition, the camera was deleted as a (probably unwise) cost-reduction measure. During flight operations, Draper returned to the SPAC, this time as director of the team.

The general philosophy for guiding the evolution of spacecraft is, according to Draper, to balance inheritance against innovation. High inheritance from previous design, or even direct inheritance of surplus parts, lessens risk and reduces cost. However, selected change is necessary in order to meet the rising expectations of spacecraft users and to stay in synchrony with the technological environment. The balance between inheritance and innovation can be determined only by engineering judgement based upon constraints and needs. The Mariner 5 mission saw the balance tipped toward inheritance because the need for change was low and the desire for cost savings was high. The Voyager mission, which we will examine, needed new technologies to function if it were to operate effectively in the distant reaches of the outer solar system.

In 1967, even before the Pioneer project received approval from Congress, NASA began to look at a Grand Tour of the five outer planets. The time was ripe because of the coming alignment of these bodies, an alignment which would permit a rapid traverse of the Solar System by a series of gravity assists.

The design for the Grand Tour featured dual launches to Jupiter, Saturn, and Pluto followed by dual launches to Jupiter, Uranus, and Neptune. In order to provide a design basis for this fleet of four spacecraft, the Thermoelectric Outer Planets Spacecraft (TOPS) study was initiated. "Thermoelectric" referred to the mode of producing electrical energy from heat generated by the decay of an isotope of plutonium. The use of solar panels for electrical power generation would not suffice in the relative darkness of the outer Solar System.

Draper served on TOPS, starting in 1967, as the spacecraft system engineer (design team leader). An important consideration was to insure reliability over the 12-year duration of the mission. The assured performance of on-board computers is essential to high reliability; so, TOPS planned a Self Test and Repair (STAR) computer. One feature of the STAR computer was the introduction of a system of voting on key decisions; three independent processors met under conditions of majority rule. If the vote was not unanimous, the dissenter, besides being over-ruled, was deemed to be flawed and a replacement was drawn from a pool of spares. In addition, the computer memory was partitioned into numerous small modules so that, in case of memory failure, a replacement module could be drawn from a pool.

Of course, protection was built into other key TOPS subsystems. In general, spacecraft designers have two methods by which they can provide protection through redundant provisions. The first method is "block redundancy," which employs an exact copy of the system to be protected. The second method, "functional redundancy," employs means other than duplication to perform the function to be protected; for example, instead of carrying two identical amplifiers, a spacecraft might carry one travelling wave tube amplifier and one solid-state amplifier. Block redundancy is cheaper and allows more total test time on the type of system to be flown. Functional redundancy is particularly valuable when the part being protected represents a relatively new technology. This form of insurance reduces the vulnerability to double failure

due to problems that could be inherent in the new technology.

But the $750 million estimated cost for The Grand Tour proved to be too high, particularly in view of the increasing cost of Viking. In early 1972 the project was told to cut back to $250 million. Another ten-day effort produced an extensive redesign which met the target cost. Savings were achieved by utilising only two spacecraft and restricting the exploration of the outer Solar System to Jupiter and Saturn. In addition to dollar savings from the lesser number of spacecraft, the new plan required less resources for mission operations and less investment in reliability; the requirement for spacecraft lifetime was lowered from 12 years to 3.5 years. Furthermore, the inheritance factor was increased by more extensive reliance on designs and spares from the Viking mission.

The new project received approval in 1972 and was christened "Mariner-Jupiter-Saturn 1977" (MJS77) to reflect its high inheritance from previous Mariners, its mission plan, and its 1977 launch date, respectively. MJS77 was later renamed "Voyager" and, after successful completion of the primary mission to Jupiter and Saturn, Voyager 2 was sent on to Uranus (1986) and Neptune (1989).

Draper, who was the Spacecraft System Engineer for Voyager, characterises the system design of a spacecraft as an iterative process. Each subsystem – radio, power, propulsion, imaging, etc. – is given a set of requirements with respect to which the subsystem engineer must produce a design. The main parameters, historically, have been mass, power, reliability, cost and science requirements. Recently, the extensive dependence of on-board systems on computers has brought the parameters of memory size and processing speed to the fore. When the subsystem designs are brought together, requirements are changed as necessary, and the design process goes through another cycle. The iterative process has recently been speeded up and made more accurate by computer-aided design and computer-aided layout of circuits. The Voyager spacecraft differed from earlier Mariner vehicles in that its complexity precluded the system engineers from having complete, detailed knowledge of the subsystems. Previously, knowledge of the individual circuit diagrams and comparable levels of detail was common.

When the Voyager spacecraft went to the Cape, Draper joined the Voyager Mission Planning Office for flight operations. The spacecraft have performed beautifully over the last ten years. On Voyager 2 the primary (block-redundant) receiver failed in 1978, but its backup is functioning well. Functional redundancy in the amplifiers proved wise since the newer type solid-state amplifier has experienced some degradation while the companion travelling wave tube amplifier has held steady. Other in-flight problems have either been accommodated within the framework of the spacecraft design or through workarounds by the flight team.

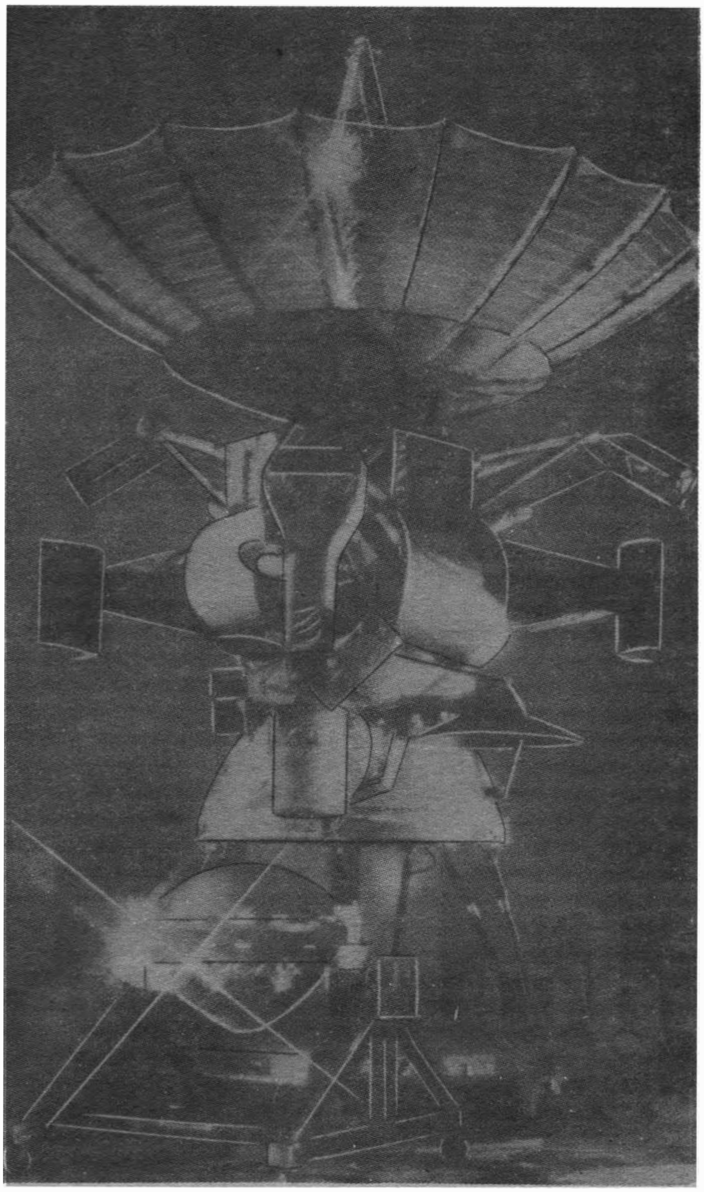
But in late 1977 a new project claimed Draper's attention – the Galileo mission to Jupiter, featuring an orbiter and an atmospheric probe. Starting as Spacecraft System Engineer, he later moved up to Orbiter Manager.

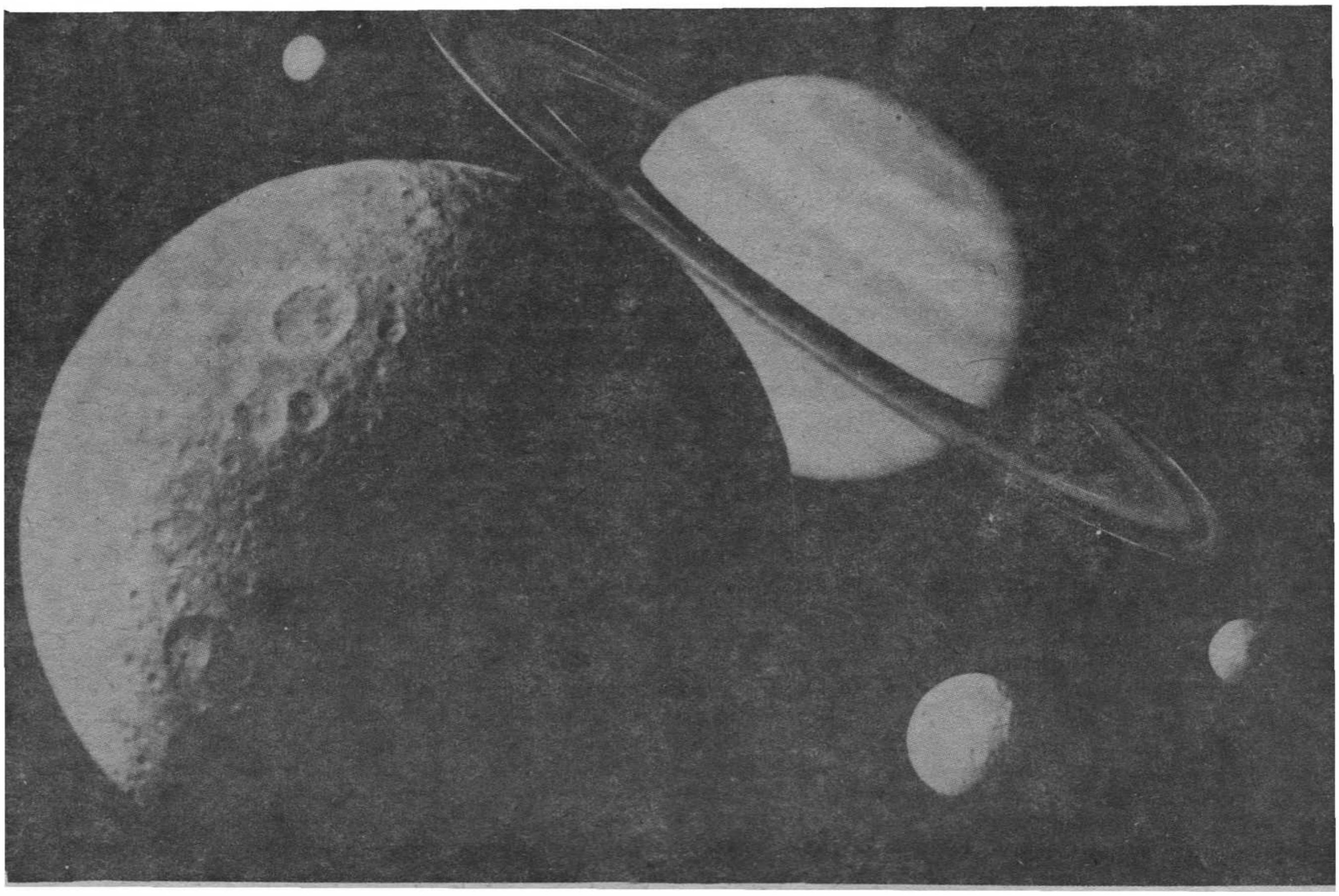
The original spacecraft design proposed for Galileo was the familiar Mariner concept of a three-axis-stablised vehicle. The orientations of two of the spacecraft axes are maintained through reference to the Sun (utilising a Sun sensor and attitude control thrusters) while the direction of the third is referenced to a selected star, often Canopus, via a star tracker. The three-axis design is simple and reliable and provides an ideal basis for remote-sensing instruments such as cameras and spectrometers. However, *in situ* fields and particles experiments are, on the whole, better served by spinning spacecraft (the Pioneer spacecraft are spinners) since the act of rotation allows the associated instruments to sample phenomena from a variety of directions.

In order to obtain the advantages of both methods of stabilisation, NASA directed the project to build a spacecraft which spun but had, also, a despun portion on which the remote sensing instruments could be located. The price for this versatility has been, of course, increased complexity.

Other Galileo challenges cited by Draper include life testing for spacecraft systems and the procurement of reliable electronic components. The component prob-

The Galileo Orbiter and Probe (below) as they sat in JPL's Spacecraft Assembly facility, prior to their scheduled May 1986 launch. The current project plan is to launch this mission to Jupiter in November 1989 with a Shuttle/IUS.





Montage of the Saturnian system constructed from images taken by Voyager 1. Dione is in the foreground with Tethys and Mimas to the right and Enceladus above.

lem has been exacerbated by the small size of the parts and the low voltages with which they operate. These factors render the computers potentially susceptible to "Single Event Upsets" wherein energy deposit from a cosmic ray or other high-energy particle can overwhelm the ongoing function and interrupt the spacecraft's programme of activity. The harsh radiation environment of Jupiter is particularly onerous for the operation of electronic parts, and Project Galileo has invested considerable effort hardening the parts to preserve their integrity.

After testing of the Galileo spacecraft was underway, Draper was appointed Project Manager of JPL's new "Mariner Mark II" series of spacecraft in September 1983. A year later his effort was focused in the role of Project Manager for the first of these proposed missions, CRAF (see the February edition of this column for recent developments on CRAF). The Laboratory hopes to get approval for CRAF as a flight project in the Fiscal Year 1989 NASA budget, now under formulation.

The experience of 25 years of spacecraft design, development and operation are being applied by Draper, with his team, in order to produce a design which balances the reliability of older subsystems with, selectively, the best that new technology has to offer.

One problem, encountered on the Voyager mission, that is being resolved for CRAF concerns the unwanted motion of the spacecraft subsequent to planned movement (slewing) of the scan platform. The four remote-sensing instruments of Voyager are located on the scan platform, which provides the pointing capability for these sensors. However, after a slew has been completed, several minutes must be allowed to lapse before the spacecraft settles down sufficiently to serve as a stable base for "jiggle free" remote sensing. During periods of cruise, provision for settling time is not a problem, but when the observation-packed planetary encounter period is underway, settling time is only grudgingly tolerated. CRAF plans to employ a momentum-compensation system for its high-precision scan platform.

The CRAF spacecraft will solve another problem by including a second, low-precision (pointing) scan platform on which are mounted the fields and particles instruments. On Voyager, these devices are bolted onto the spacecraft and have limited freedom to sample their environment in several directions. Locating them on a scan platform confers some of the benefits of a dual-spin spacecraft on the three-axis stablised CRAF without incurring attendant complexity of design.

Additional reliability is being put into CRAF through the introduction of fiber-optics sensors into the gyro system in a joint effort with Bell Telephone Laboratories. With no moving parts, the tendency of mechanical systems to fail by simply wearing out is eliminated for this key component of the attitude control subsystem.

With the loss of the Centaur G-prime as a high-energy upper stage for the Shuttle, efficiency in spacecraft propulsion systems is a high-priority item for all projects. CRAF is exploring the feasibility of increasing the capability of its propulsion system by six per cent through use of a rhenium throat engine. If

the technological upgrade is implemented it would permit augmentation of the scientific payload by raising the spacecraft mass constraint and would also allow more mission flexibility.

Cost reduction through technological advance is being achieved on CRAF with the introduction of solid-state X-band amplifiers, which cost one-half the price of travelling wave tubes and are now items of proven reliability (CRAF will be an X-band only spacecraft).

Subsystem power and mass reductions of more than a factor of three are being made with utilisation of the ASTROS 2 star tracker (based upon the ASTROS 1 system which was to have been launched, after Challenger, for NASA's Halley's comet observations).

Not all of the CRAF improvements relate to hardware advances. Most spacecraft on-board computers are programmed in whatever machine language is applicable. This results in memory savings and processing-time reductions over the alternative of coding in a high-level language such as FORTRAN, ALGOL, or C. However, continuing advances in microprocessors have resulted in the availability of space-qualified devices of sufficiently large capacity and speed to employ C. The savings in programming cost and the gain in intelligibility, for the human partners of the spacecraft, are considerable.

The excitement and scientific returns from the exploration of a comet at close range are the principal rewards that we will obtain from CRAF; imagine watching the gnarled and wrinkled nucleus beginning to sputter as it approaches the Sun! But the spectacle of these achievements is only possible through the skills of Ron Draper and his colleagues who are combining the best of the past and the present to yield the future. He remarks: "The team effort is very important in all of these activities. I have had exceptionally capable and dedicated people working these challenging tasks as members of the teams."

Magellan to Venus

The Magellan mission to Venus is scheduled for launch with a Shuttle/IUS in April 1989, the first launch of a NASA planetary mission in 11 years. It will arrive at Venus in August of 1990. The unusually long transit time from Earth to Venus (normally the passage is made in somewhat over three months) results from the loss of the Centaur as a high-energy upper stage for the Shuttle and the necessity to reschedule launches. The purpose of the mission is to acquire a high-resolution radar map of most of the planet's surface. For more details of the mapping process see the May 1985 edition of this column, wherein Magellan is referred to as the Venus Radar Mapper – its former name.

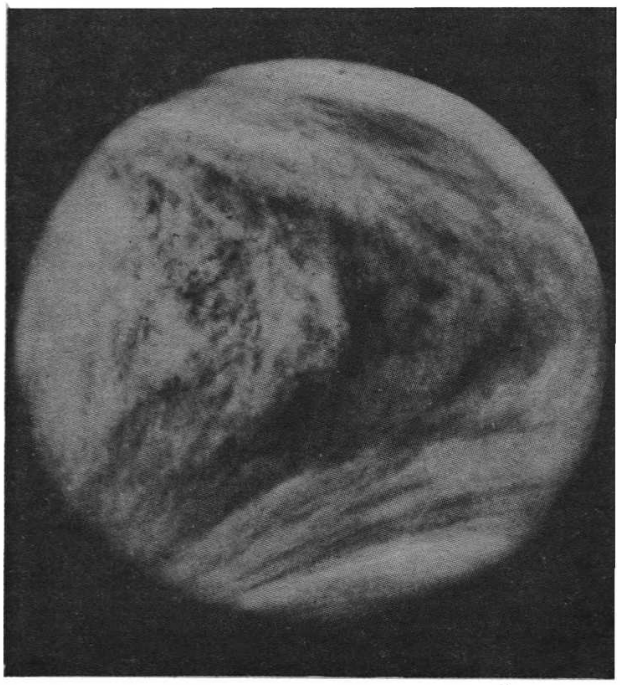
In the preceding piece we discussed a series of spacecraft that had been built via the "in house" mode, i.e., largely at JPL. The alternative mode for the Laboratory is to let a systems contract and have the spacecraft built "out of house". The Magellan spacecraft is being built in the latter mode with the Martin Marietta Company (MMC), Denver, as the contractor. The second major contractor, the Hughes Aircraft Company, is constructing the synthetic aperture radar (SAR), with JPL furnishing some of the associated digital electronics for this instrument.

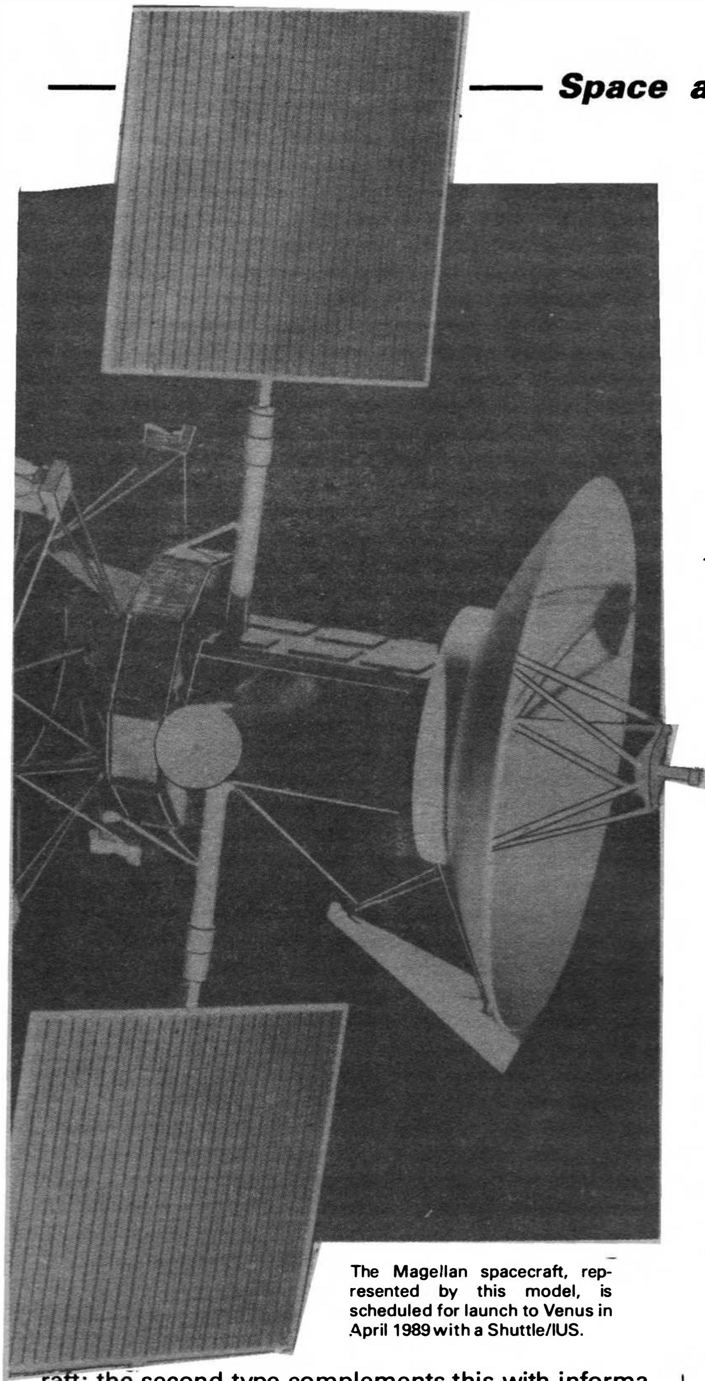
A significant project milestone is scheduled for June/July of this year when the spacecraft and a prototype of the radar will be tested together at MMC. Last summer a prototype of the radar was tested with the command system of the spacecraft to assure the soundness of their functional relationship. The upcoming testing will validate the proper operation of a more complete set of hardware. Then in January of 1988 the flight radar system and the spacecraft will start a series of tests to exercise not only the flight hardware but also elements of the supporting ground system. In November 1988 the entire system will be shipped to the Cape for testing and launch vehicle integration.

Allan Conrad, Manager of the Mission Operations System, described some of the challenges that the Magellan project faces in navigation, data handling, and operations.

Precision navigation of the spacecraft, as it swings about Venus in its 3.15 hour, highly elliptical orbit, is important because the radar must be pointed accurately (0.20 degrees or better) during the mapping segment of each orbit; about half of this uncertainty in pointing will be due to navigational uncertainties and half ascribable to the spacecraft. For navigational purposes, the line-of-sight velocity of the spacecraft, measured by tracking the doppler shift of its X-band radio signal received at antennae of the Deep Space Network (DSN), is required to be accurate to within six-tenths of a millimeter per second, and a second type of tracking data (technically, "delta-differenced one-way doppler") must be known five times more accurately than this. The first data type yields dynamical information along the line-of-sight from the station to the spacec-

This full-disk view of cloud-shrouded Venus was taken by the Pioneer Venus Orbiter in 1979 from a distance of 40,600 miles. The image of a cloudy, turbulent atmosphere clearly shows the bright cloud masses which are wrapped around both poles. The characteristic "Y" marking, clearly visible in many images, is only faintly visible in this view but it appears to cover most of the central part of the disk. The large, Y-shaped feature may represent dark sulphur clouds lying within the reflective, higher cloud layer. Scientists think the marbled cloud pattern near the centre of the picture represents convection cells (self-contained areas of cloud movement) caused by the Sun's heat.





The Magellan spacecraft, represented by this model, is scheduled for launch to Venus in April 1989 with a Shuttle/IUS.

raft; the second type complements this with information about dynamics perpendicular to the line of sight.

These measurements of the radio signal will be translated into position and velocity estimates for the spacecraft in its orbit about Venus by use of mathematical models of this motion. Analogously, astronomers translate the doppler-determined line-of-sight velocity of a distant galaxy into the galaxy's distance from Earth, employing a mathematical model of the expansion of the universe (Hubble's law).

The most obvious fact about data on Magellan is that there will be a lot of it! The large volume of data is a characteristic associated with synthetic aperture radars. We experienced this condition on the oceanographic satellite Seasat (1978 launch) which carried a SAR in its complement of instruments. An intuitive grasp of the reason for the large volume of data can be obtained by noting the crisp, detailed SAR images returned from Seasat and imaging radars contained on two Shuttle flights.

For just over 37 minutes of its orbit, when it is closest to Venus, the SAR will illuminate the planet with microwaves and record the returned signal at the rate of 806 kilobits per second (790 due to the radar and 16 from associated engineering measurements). Then, the spacecraft will turn to point its 3.7m antenna, a spare from Voyager and the same antenna used by the SAR system, to Earth for return of the data. For 114 minutes the antenna will broadcast at the rate of 268.8 kilobits per second the highest rate achieved by any interplanetary spacecraft (for comparison, Voyager's maximum rates in kilobits per second were 115.2 at Jupiter, 44.8 at Saturn, and 21.6 at Uranus).

The mapping phase for the primary mission of Magellan will span 243 days. At the front end, one to two weeks are required for in-orbit checkout of the spacecraft. The mapping phase itself will suffer an interruption of a few days at superior conjunction, when Venus is very close to the apparent location of the Sun, disrupting the radio signal from the spacecraft. Assuming that an extended mission is authorised after the completion of the primary one, it will be used to fill in holes in the global radar map of Venus and to perform special scientific studies.

The large volume of data scheduled for receipt at the DSN stations requires, under current plans, that it be put on tapes to be shipped to JPL for processing, as opposed to direct electronic transfer of data from the stations to JPL. However, it is necessary to evaluate on a regular basis the performance of the radar system. Thus, six per cent of the data received at the Goldstone, California DSN station will be sent to JPL by electronic means, for evaluation the next day.

After 30 to 40 days of mapping operations the data "pipeline" will be producing a steady input to JPL, and the data processing system at the Laboratory will produce a day's worth of radar images for each day of spacecraft mapping.

The project has established a Data Management Archive team to provide a unified, indexed store of all project data: scientific and engineering. The centralised data are accessible by all investigators and will be delivered *en masse* to the Planetary Data System after the mission for permanent national archiving.

The third challenge described by Conrad, flight operations, will be the first operations to utilise JPL's new Spacecraft Operations Center (SFOC) – a collection of hardware and software systems organised for multimission support. See the paper by M. Ebersole in the October 1985 issue of ***JBIS*** for a description of SFOC. For Magellan, only the downlink aspect of SFOC will be employed. Uplink (commanding the spacecraft) will use classical JPL systems. Subsequent missions will draw upon SFOC's uplink facilities.

Another distinction for Magellan operations is the planned use of remote spacecraft-analysis support from MMC in Denver, at non-critical times of the mission. At crtitical mission phases – launch, trajectory correction manoeuvres, insertion into orbit about Venus – these expert analysts will provide real-time support of the spacecraft at JPL.

The project's desire to minimise costs has yielded plans to limit operational activities, and, hence, staffing levels. The uplink of new computer loads (sequences) to the spacecraft will be restricted to three times per week, and it is a project goal to staff most operations teams for only five-day, 40-hour weeks. A few critical teams, including the data processing people, will need to function for seven days per week.

The Magellan mission will furnish the basis for a global characterisation of the geology of Venus, much as Mariner 9 did for Mars 15 years ago. It will also start to get the planetary programme back on track.

Space Mathematics

Space flight as we know it depends upon many technologies: propulsion, communications, digital computers, electronics, systems engineering, etc. Underlying all of these disciplines is that ancient treasure of civilisation, mathematics. The bulk of the relevant mathematics supports the basic physics and engineering that are applied in a space setting, but some mathematics has a more direct connection to our field. We will look at how two mathematical concerns of the Greeks, geometry and logic, and a product of the eighteenth century, a specialised problem in dynamics, have smoothed the way to the Moon and planets.

"Conics," those mathematical curves classifiable into ellipses, parabolas, and hyperbolas, are so named because they can be generated by slicing a cone with a plane, yielding a "conic section," which is the proper name for this object. In fact, conic sections in everyday life are visible on the walls and ceilings of a room when a lamp is turned on. The usual lamp shade will shape the light emerging from its top end into a cone, and the section of this cone by the ceiling yields a circle (a special case of an ellipse) while the wall slices a hyperbola from the light cone.

Mathematically, conic sections were discovered by the Greek geometer Menaechmus, who flourished in the middle of the fourth century BC. The definitive work on the subject was published in the third century BC by the "great geometer," Apollonius of Perga, whose *Conics* is still worth reading.

The connection of conics with celestial phenomena was made by Johann Kepler in his *Astronomia Nova* (1609) wherein he demonstrated that the planets move (approximately) in elliptical orbits about the Sun. Incidentally, he also showed that a parabolically shaped mirror would focus parallel rays of light. With these two conically based discoveries, he paved the way for Newton's deeper researches into celestial mechanics and Newton's invention of the reflecting telescope.

Conics have long been useful in the initial design for spacecraft trajectories. Although advances in computer services have made more accurate methods of trajectory analysis quite accessible, the trusty conic still remains a staple of the art of mission design due to its simple representation of a flight path.

Another major contribution from classical Greece was the virtual invention of formal logic by Aristotle (384-322 BC). It is surprising that such a fundamental subject was brought to being by one person, and no major advances beyond Aristotle were made until the nineteenth and twentieth centuries of our era. George Boole (1815-1864) founded modern symbolic logic which, along with subsequent methods and results of great power, developed by a string of creative European logicians, has opened new vistas for computer science, including the subject of symbolic processing.

We have departed somewhat from the charter of this piece to cite a discipline that does not contribute directly to space science, but the effect is nonetheless powerful when transmitted through the medium of symbolic techniques which include expert systems and artificial intelligence as subdisciplines. The January and February editions of this column described advances in these areas. Logical ideas permeate the study of the structure of formal languages, which are important as a link between our carbon-based brains and the silicon structures of the computer. Probably the basic reason for desiring automation in space is, for the unmanned programme, the long, untended periods of time that our creations must spend without direct human guidance.

The physicist John Wheeler has speculated that logic may form the basis for the next great revolution in physics, and the traditional role of logic in philosophy continues, possibly even growing in significance. Thus, Aristotle's conception has travelled over two millennia in time, into outer space, and into the intellectual roots of our world.

Chess has proved to be a fascinating game, judging by the time that humanity has invested in it over the centuries. One explanation for this attraction is that the game is located in the zone between the readily comprehensible, games that are too simple, and constructions that are too complex to be grasped with profit – perhaps one might place three-dimensional chess in the latter category.

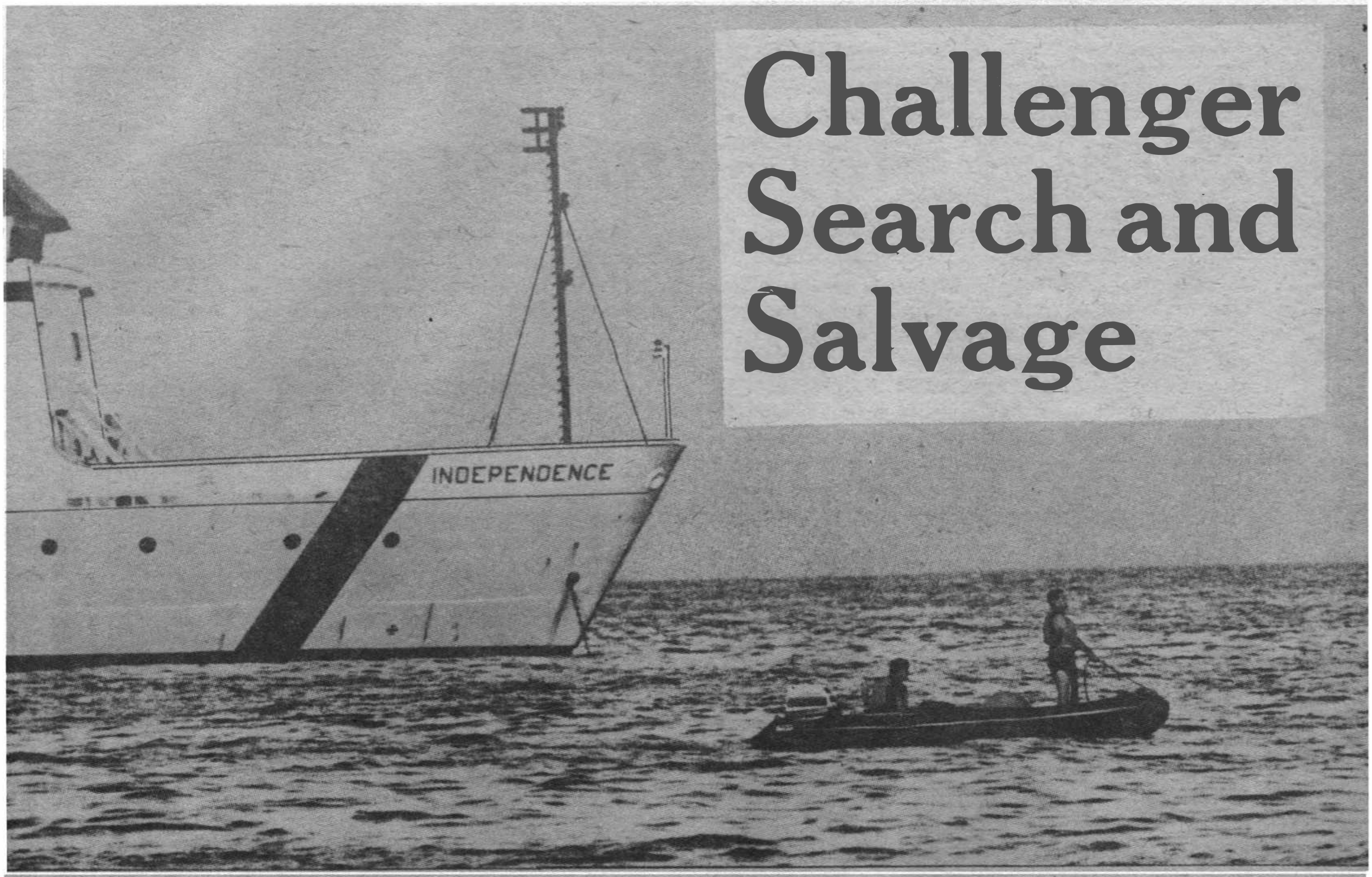
There is a problem in dynamics that seems to owe much of its vitality to this type of delicate suspension between the too simple and the overly complex: the restricted problem of three bodies (R3B). The problem of two bodies (in its idealised form), say the Sun and one planet, was solved completely by conics in the work of Kepler, as described earlier. The task of determining the motions of three or more gravitationally interacting bodies is, in contrast, too difficult to solve analytically; one must resort to numerical approximations. The "restricted" problem of three bodies is formulated by considering the motion of a small body, of negligible mass, moving under the gravitational influence of two relatively massive bodies. The two massive bodies move in conic sections with regard to one another, by a Keplerian analysis, since the small third body is assumed to have no effect on their paths.

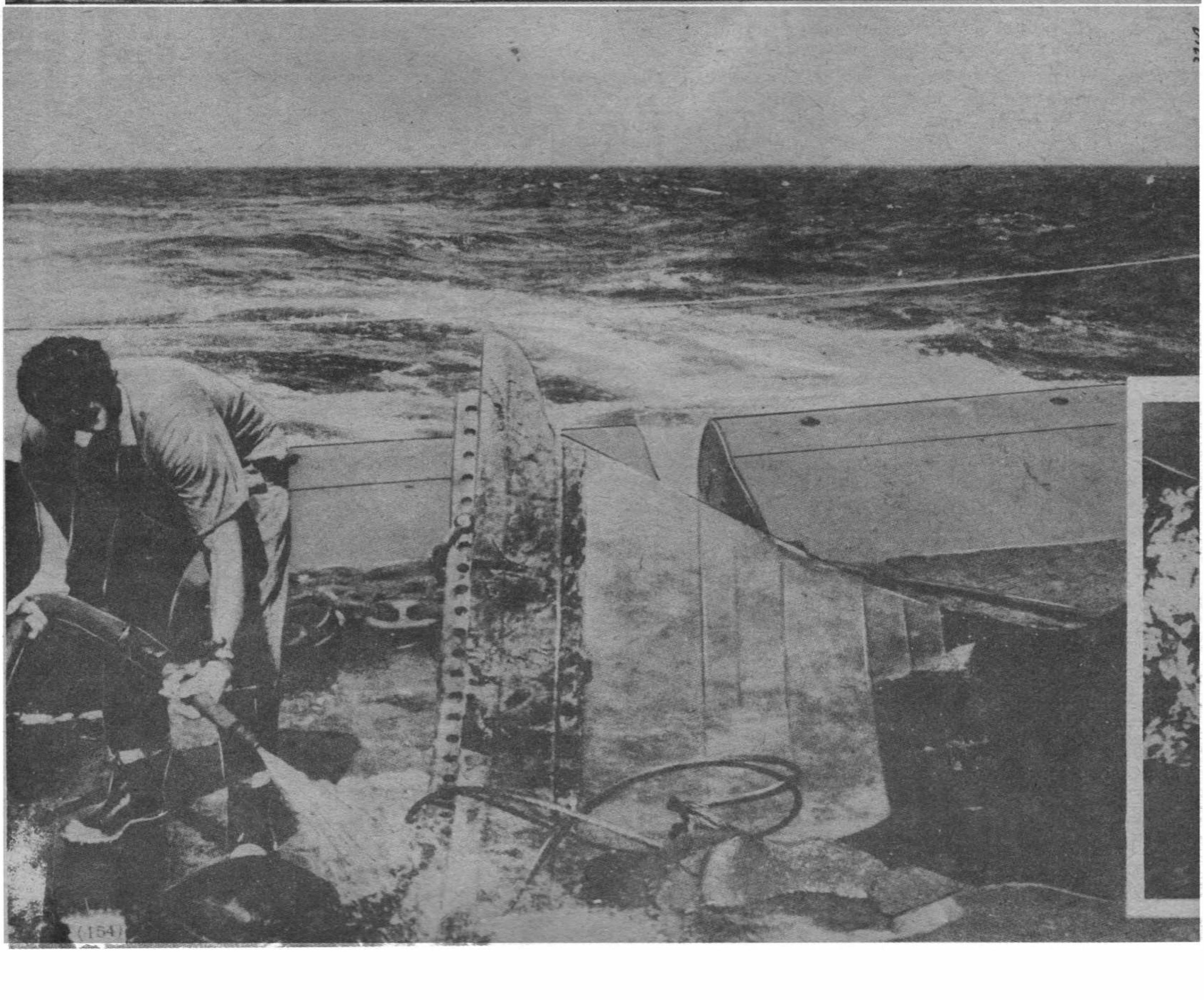
One physical system that can be approximated by R3B is the case of a spacecraft moving under the influence of a simplified model of the Earth-Moon system (the two massive bodies). And, in fact, R3B has demonstrated considerable utility in the investigation of spacecraft trajectories for lunar missions, particularly during the Apollo era.

A famous astronomical example with respect to R3B is that of the Trojan asteroids. This family of small bodies is primarily governed by the gravitational forces of the Sun and Jupiter (the two massive bodies) and traces out one of the few exactly known trajectories for R3B. The theoretical possibility of such a situation was shown in 1772 by the Italian-French astronomer and mathematician Joseph Lagrange (1736-1813). The first Trojan asteroid, 588 Achilles, was not discovered until 1906, and many others have subsequently been added to the list.

Who should be given the credit for originating the idea of R3B is a matter of some dispute, but the Swiss Leonhard Euler (1707-1783), the most prolific mathematician in history, is often mentioned. In the last two centuries, hundreds of papers and books have appeared on the theory of R3B, and impressive advances have occurred, but full analytical comprehension eludes investigators and, indeed, may never be achieved.

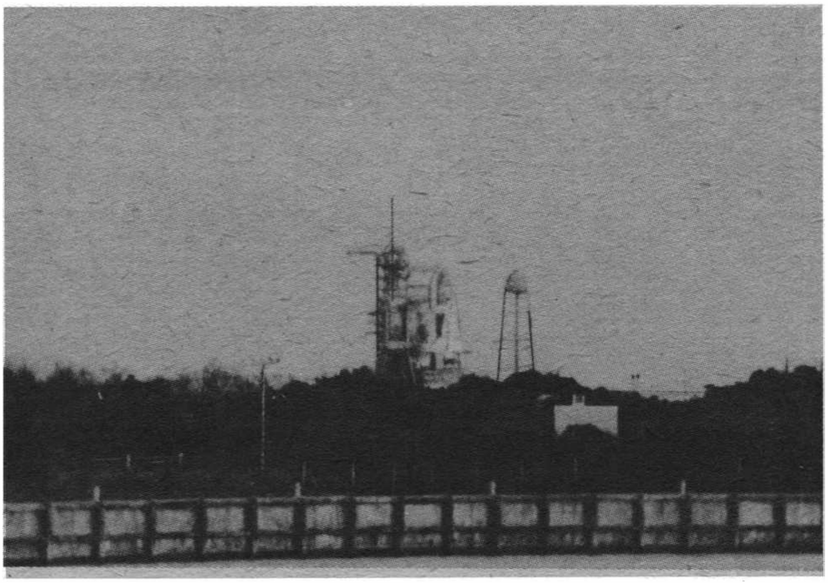
Challenger Search and Salvage





by Joel W. Powell

Seven months to the day after the tragic Challenger accident on January 28, 1986 the largest search and salvage operation ever conducted was brought to a close. Thirty eight surface vessels and 6000 armed forces and contractor personnel had scoured the Atlantic Ocean near Kennedy Space Center to locate remnants of the Shuttle for use in the post-accident investigation.



The author took this shot of the scene at Launch Complex 39B prior to the launch of Challenger on mission 51L. *J.W. Powell*

Surface Search

Debris literally rained from the sky for 45 minutes after the Space Shuttle Challenger erupted into an enormous fireball only 73 seconds after lift-off. Television monitors at Kennedy Space Center showed pieces of the Shuttle splashing into the sea relayed from a camera atop the Vehicle Assembly Building (VAB), while echoes from falling debris cluttered downrange radar screens. The only sign of debris visible from the chilly viewing areas was a drogue parachute from one of the SRB's drifting in the cloudless sky.

Helicopters and fixed wing aircraft were airborne within two minutes of the explosion at 1139 local time, but were forced to orbit outside the projected impact zone until the all-clear was given by the Range Safety Officer (RSO) at 1237. Floating wreckage was spotted almost immediately by the searchers.

As the afternoon progressed NASA and Air Force representatives assembled a search team to be led by USAF Col. Edward O'Connor. The SRB recovery ships Liberty Star and Freedom Star were recalled from their stormy stations on the Atlantic and the Coast Guard was ordered to provide cutters to retrieve floating debris. By 1800 there were 12 aircraft and ten ships combing the ocean surface for the remains of Challenger.

In the early morning darkness of January 30 the Coast Guard cutter Dallas returned to the Trident Basin at Port Canaveral with five large pieces of Shuttle wreckage. Jagged portions of the right wing and fuselage were unloaded in addition to a 7.6 m piece of the outer shell from the crew compartment. Ironically a prominent yellow 'Rescue' decal was visible on the tiles.

There was a sense of urgency to the surface search because the Gulf Stream current was gradually carrying the debris north of the impact area. The search zone initially extended South of Cape Canaveral to Cocoa Beach and north to Daytona Beach, covering an area of 12 959 km^2. A total of 270,000 km^2 of the Atlantic was eventually searched for floating debris by the close of the surface search on February 7.

Besides innumerable bits of TPS tiles and pieces of the fuselage, the Coast Guard and Navy managed to retrieve speed brake panels from the vertical tail, the body flap control surface, parts of the cargo bay doors and the top of the External Tank with vent tip intact. Astronaut helmets and middeck lockers were also found floating near the crew impact site in early February.

SRB Salvage

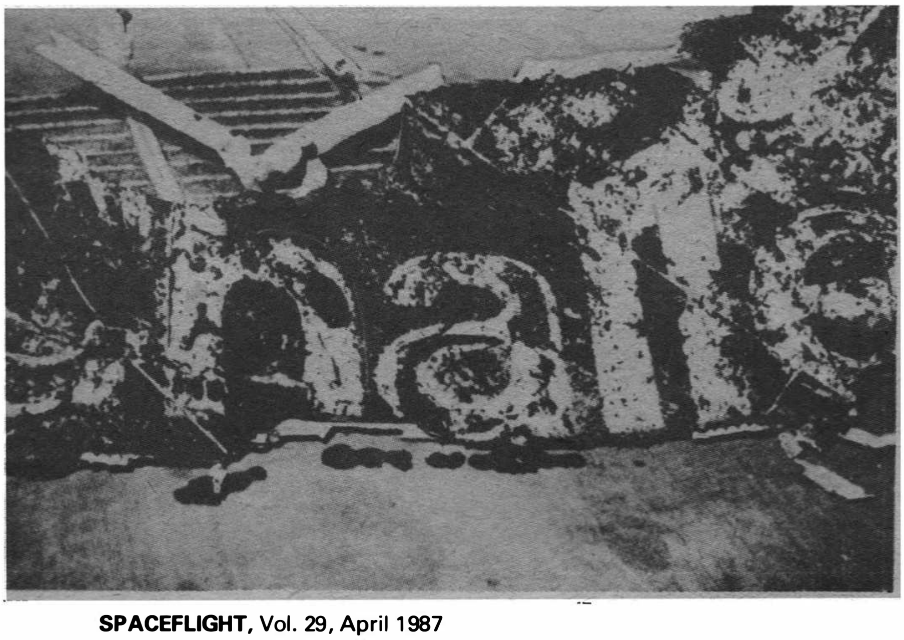
Less than a week after the accident a probable cause had emerged. On February 2 NASA released a video tape of the ascent showing an unusual plume of flame streaming from the right hand solid booster of Challenger. The plume was apparently emanating from a hole burned through the lowermost connection between the four SRB segments and appeared to trigger an explosion of the external fuel tank.

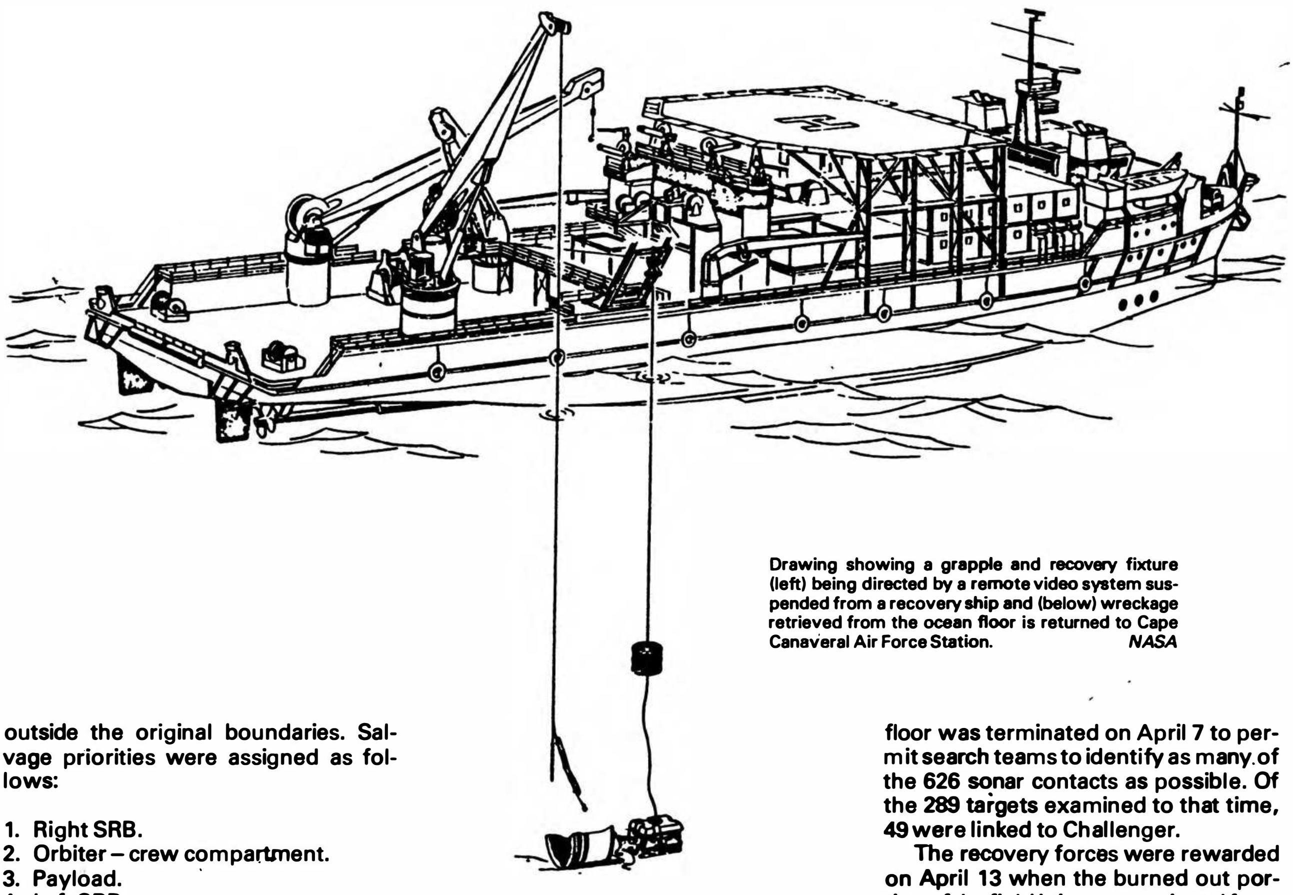
The search for the right hand SRB was undertaken by an impressive array of underwater salvage equipment owned by the Defense Department and leased from commercial diving and oil well servicing companies. The Navy salvage ship USS Preserver served as lead vessel and heavy lifting chores were performed by the G.W. Pierce and the Stena Workhorse from Scotland.

Manned submersibles were operated by the underwater survey ships Seward Johnson and Edwin Link to attach lines and examine debris in deep water. Stena Workhorse, the SRB recovery ship Independence and the USS Opportune were also equipped with unmanned Remote Operating Vehicles (ROV) to supplement the efforts of the diving teams that worked in shallow water to a depth of 91 m.

Side-scan sonar was used to look for the right SRB in an area just off shore from Kennedy Space Center, where radar had indicated the impact of booster fragments. The 745 km^2 search zone was extended to 1252 km^2 after SRB remains were discovered

Two days after the accident two sailors in a Zodiac boat (above left) search for floating Challenger debris near one of the SRB recovery ships. In the picture at left a deck hand hoses down the exposed propellant grain of a newly recovered SRB fragment to lower the risk of accidental ignition. *Below,* a portion of the heat protective blanket from the right wing bearing the name *Challenger.* NASA





Drawing showing a grapple and recovery fixture (left) being directed by a remote video system suspended from a recovery ship and (below) wreckage retrieved from the ocean floor is returned to Cape Canaveral Air Force Station. *NASA*

outside the original boundaries. Salvage priorities were assigned as follows:

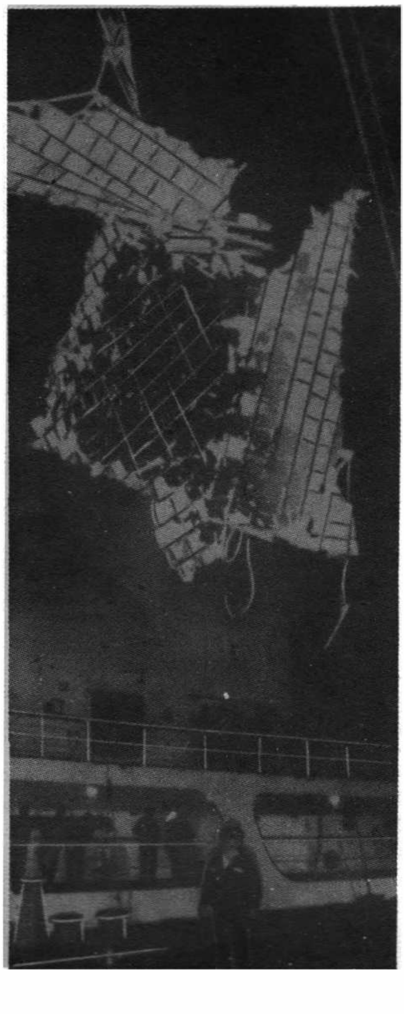
1. Right SRB.
2. Orbiter – crew compartment.
3. Payload.
4. Left SRB.
5. External Tank.

NASA announced on February 19 that specific pieces from the right SRB had been located by the manned mini-sub Sea Link 2 and a video tape was released showing a submerged hydraulic fluid reservoir from the SRB auxiliary power unit, The 53 cm component, which was recovered by the mini-sub, was positively identified from its serial number.

With the general locale of the right SRB having been established, an intensive hunt for the booster was set in motion. The Sea Link 2 and three unmanned ROV's were joined by the Navy's small nuclear powered research submarine NR-1 to conduct a comprehensive sonar and video survey of the entire SRB "debris field" over a period of 60 days.

When a piece of an SRB believed to be from the left side was located by the Sea Link 2 on February 22, the head of salvage decided to raise "sonar contact 11" to serve as a rehearsal for retrieving the critical right booster. After attaching a cable by submersible, salvors struggled for a week before the 2.1 m piece of the aft skirt was brought to the surface on March 8.

Hopes of finding the failed joint were intensified on March 18 when Stena Workhorse recovered part of the right SRB casing. The 1.5 m fragment was from an undamaged section of the aft field joint. Sonar mapping of the sea floor was terminated on April 7 to permit search teams to identify as many of the 626 sonar contacts as possible. Of the 289 targets examined to that time, 49 were linked to Challenger.



The recovery forces were rewarded on April 13 when the burned out portion of the field joint was retrieved from a depth of 168 m about 74 km northeast of Pad 39B. Known as sonar contact 131, the 1861 kg piece of metal was part of the tang, or 'male' segment of the aft booster seal. A large hole with an area of 0.186 m^2 was burned in one corner centered on the 305 degree position of the circumference. There was no trace of the O-rings.

Another two weeks were required to locate the corresponding clevis ('female') section where the burn-through occurred. The 3 m case fragment, designated sonar contact 712 was eagerly hauled aboard the Stena Workhorse on April 29. With word that the bottom half of the seal had been found, Col. O'Connor called a halt to deep water recovery efforts from May 1.

Due to the presence of hazardous solid propellant the SRB debris was handled differently from the other salvage. Before the remnants were examined at Hanger "O" in the Industrial Area of Cape Canaveral the residual propellant was literally burned away by thermite charges at the Explosive Ordnance Disposal (EOD) Range.

The controlled burns prevented further damage to the battered debris and permitted inspection to be conducted in complete safety. An exception was made for the two pieces of the failed joint in order to make a detailed examination of the inner surface of the propellant grain. The investigators

concluded that the cold-affected joint did fail as ascertained from the tracking camera records, but that the recovered wreckage added little to what was already known.

The Crew Compartment

Although the crew compartment was high on the priority list, the announcement of its discovery nonetheless came as a shock to the outside world. The painful finding was made on March 7 from the salvage vessel "LCU" anchored about 33.3 km NE of Pad 39B. According to *Florida Today* newspaper, divers Mike McAllister and Terry Bailey were investigating a large sonar contact at a depth of 26.5 m when they came across a jumbled heap of wreckage 1.8 to 2.4 m high. Out of the murk loomed one of the EVA spacesuits with the feet floating freely toward the surface. Knowing that the suits were stored in the orbiter airlock, the startled divers realised that they had located the crew cabin of Challenger.

Recovery of wreckage and human remains began in earnest the following day. After nightfall the USS Preserver returned to port bearing the first recovered debris and, possibly, astronaut remains. It was the first of many solemn homecomings for the Preserver in the following weeks.

Late on March 12 the Preserver stole into port without running lights and was met at the dock by several ambulances. Flag-bearing containers on deck, flanked by an honour guard, were transferred to the ambulances and were driven to the NASA Life Science Facility at Cape Canaveral where forensic examinations would be performed on the bodies. The remains of the astronauts were reportedly in unrecognisable condition.

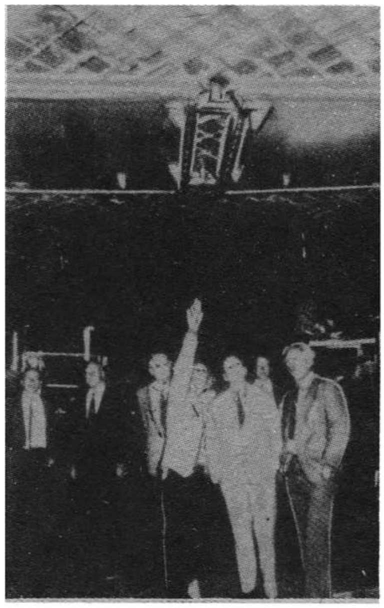
Flight Recorders

Among the debris off-loaded from the ship were the five orbiter flight data recorders and four of the general purpose computers. The flight recorders were immersed in fresh water and flown to Houston for an attempt to decipher the recordings. The magnesium take-up reels had oxidised in the sea water, binding the tapes together, and IBM developed a clever process to break down the magnesium dioxide so that the tapes could be unwound for restoration.

A tape of the astronaut's final comments over the intercom proved to have the most impact. The transcript that NASA released on July 17 seemed to prove that the astronauts were not aware of their predicament but 11 days later the space agency was forced to admit that at least one crew member was aware of the situation. Further analysis of the tape revealed that pilot Michael Smith uttered "uh-oh!" just as electrical power was lost. Gauges on the instrument panel were registering main engine shutdown and the vehicle was experiencing noticeable yawing motions as he spoke.

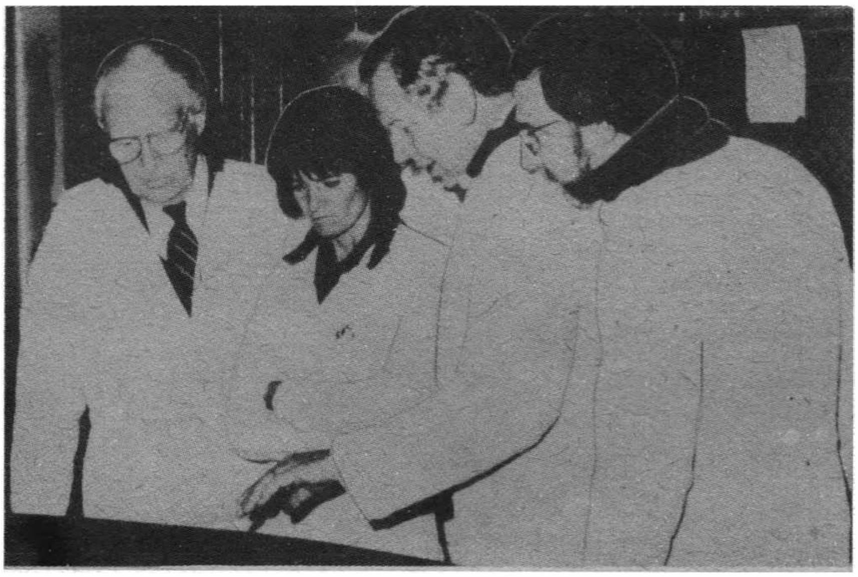
At least 75 per cent of the crew cabin was eventually recovered and the Rogers Commission Report contained a list of over 1200 individual pieces of cabin wreckage stored in a restricted area of the Logistics Facility warehouse at Cape Canaveral. The largest piece of the crew module was a 5.2 m section of the '576' bulkhead that faced the cargo bay. The airlock exit hatch was completely intact as was one of the rear window openings. Further photographs of the cabin will *not* be released out of respect for the astronauts' families.

After storms stirred up the sea bed at the cabin site in early April, a commercial scallop boat named Big Foot was engaged to successfully trap silt-covered debris with nets. Video surveys were then made by submersible and divers searched the bottom to make sure that none of the module remained undetected. The poignant task of crew cabin recovery ended on April 18 after the last of the astronaut remains, those of Gregory Jarvis, were discovered three days earlier. The bodies were flow to Dover, Delaware on April 29 to be turned over to the respective families.



Members of the Presidential Commission inspect Challenger wreckage. *NASA*

William Rogers (left) and other members of his investigation team, including astronaut Sally Ride. *NASA*



Reconstructing the Accident

On April 9 the head of the National Transportation Safety Board team that was officially investigating the accident, Terry Armentrout, led the media on a tour of Challenger wreckage at the Logistics Facility. The barnacle encrusted debris was arrayed upon a grid marked on the floor in 2.1 m squares to mark the approximate place of origin on the orbiter.

Armentrout revealed that the Challenger broke up due to aerodynamic forces and structural overload rather than the effects of the actual explosion. When the right SRB came loose from the lower strut at T+72 seconds, the External Tank had already been leaking hydrogen for nearly eight seconds after being breached by the plume from the faulty seal.

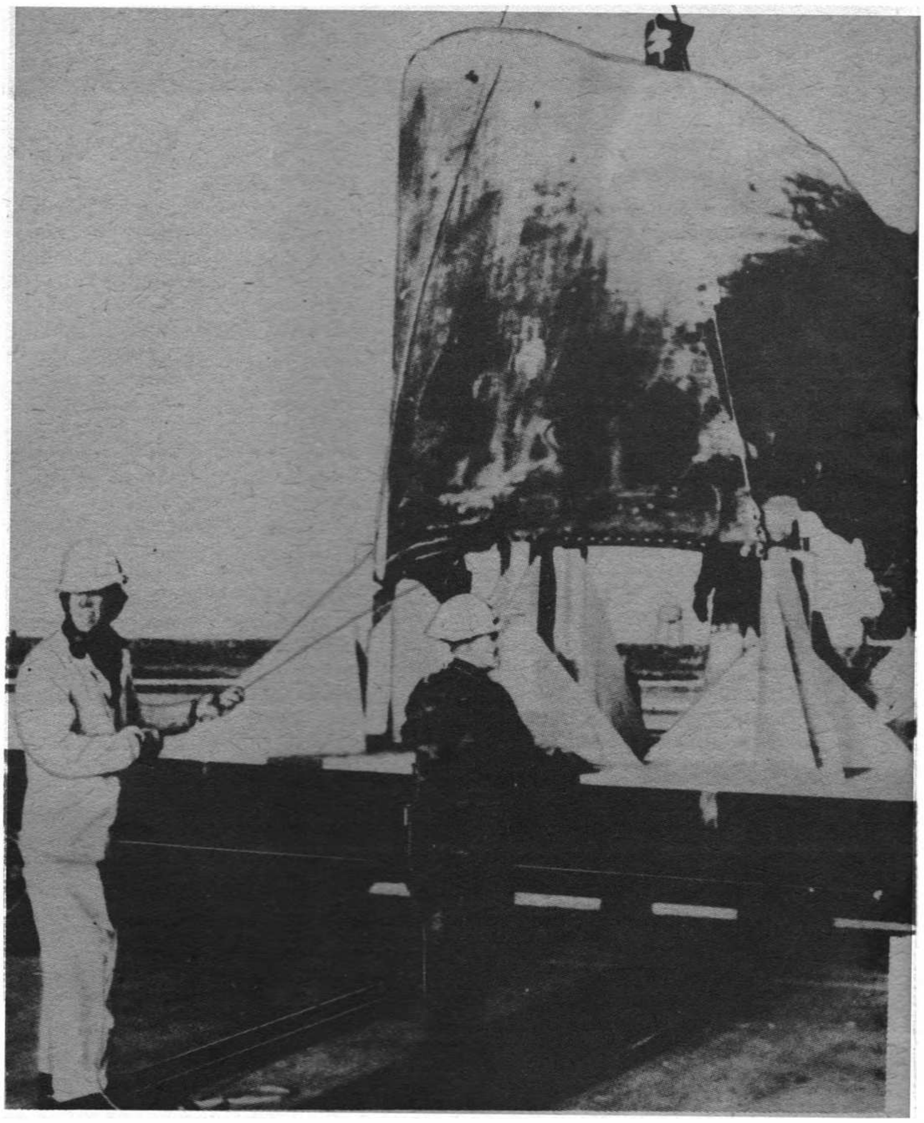
Within one second the lower dome of the ET failed and the liquid hydrogen spilled out, exerting an upward force of thirteen million Newtons. The pivoting SRB contacted the intertank section just as the hydrogen tank was forced up into the oxygen tank structure, rupturing it. The orbiter was thrown clear and broke into several pieces as the hydrogen and oxygen were ignited by the booster exhaust. Both SRB's con-

tinued on independent trajectories until they were destroyed by the Range Safety Officer (RSO) 37 seconds after the explosion.

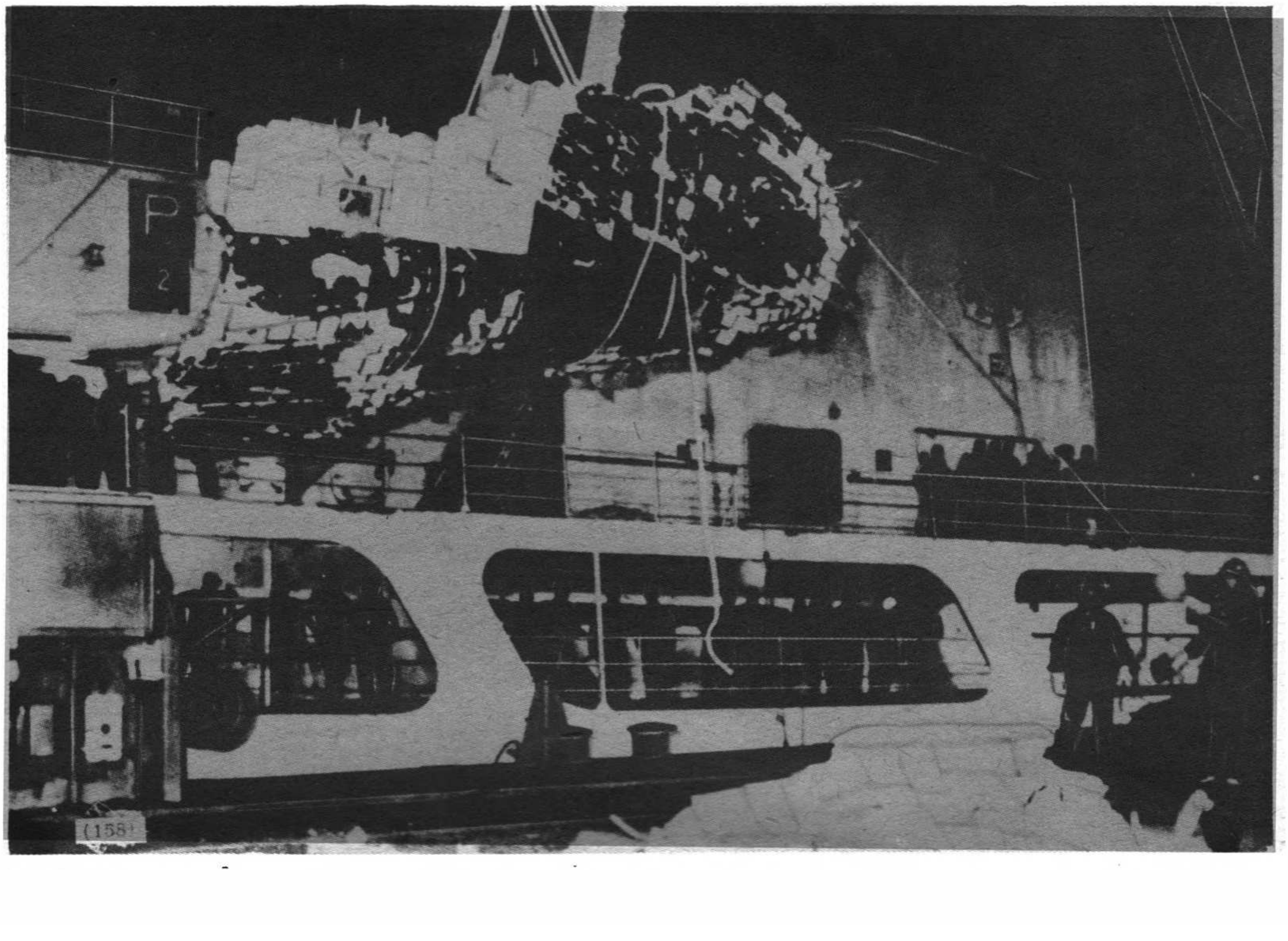
Matching indentations on the right SRB frustrum and ET intertank panels provided proof that the SRB struck the External Tank. Gouge marks on the underside of the right wing indicated that the runaway booster also severed the wing and probably helped dislodge the orbiter. Fire damage on the spacecraft was confined to the vertical tail and right sidewall. The presence of solid propellant combustion products indicated that exhaust streaming from the aft field joint caused the charring.

Tracking films revealed that the cabin separated cleanly from the payload bay and plunged into the ocean essentially intact. Structural fracture patterns and the close proximity of the debris on the sea bed demonstrated that the crew compartment was ~~obliterated when~~ it struck the water with a force of 200 G's and a velocity of 333 kph. The module was in a nose down attitude and was banking to the left at impact, and the greatest damage occurred on the left side below the entry hatch.

Prelimiary evidence indicated that the crew were dead or unconscious



A 4000 lb piece of the aft centre tang joint of the right SRB is unloaded from the Stena Workhorse (right). It was recovered with the assistance of the unmanned submersible Gemini, 35 miles north east of Cape Canaveral in 560 feet of water. *Below:* the USA Coast Guard Cutter Dallas returns wreckage to the Cape Canaveral Air Force station.
NASA



immediately following the explosion but in July a report by Dr. Joseph Kerwin of the Johnson Space Center concluded that forces reached only 12 to 20 G's for a brief moment and should have been survivable. Investigators were unable to determine whether the cabin lost pressure during the accident because structural damage at impact was so severe. The astronauts would have retained consciousness for up to 15 seconds in the event of cabin decompression at 14,630 m altitude where the disaster occurred.

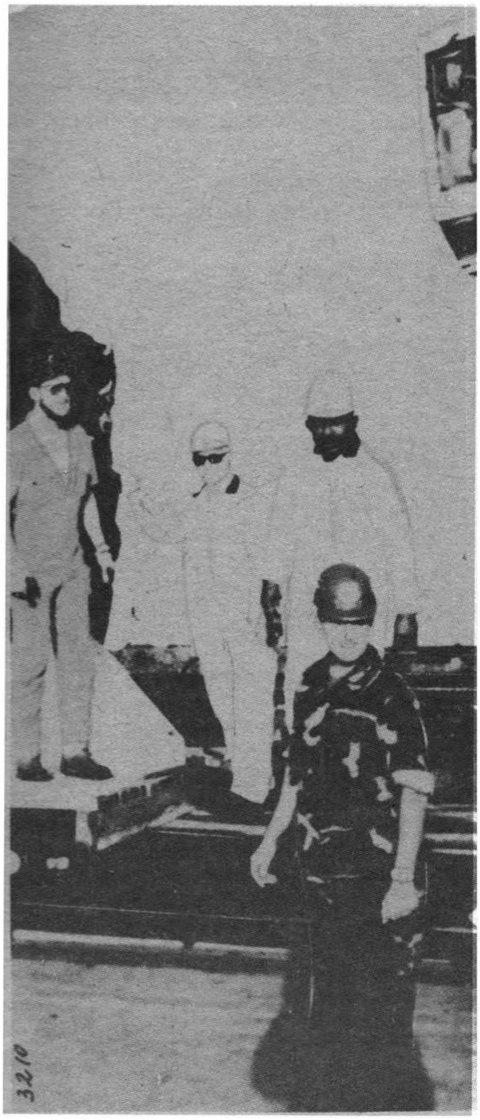
At the same time that NASA admitted the flight crew were aware of their peril, the space agency also disclosed that four Personal Egress Air Packs (PEAP) had been recovered from the Shuttle cockpit. Three of the air packs, provided for emergency evacuations at the launch pad, had been activated manually even though the ordinary air available would not have prevented loss of consciousness at high altitude.

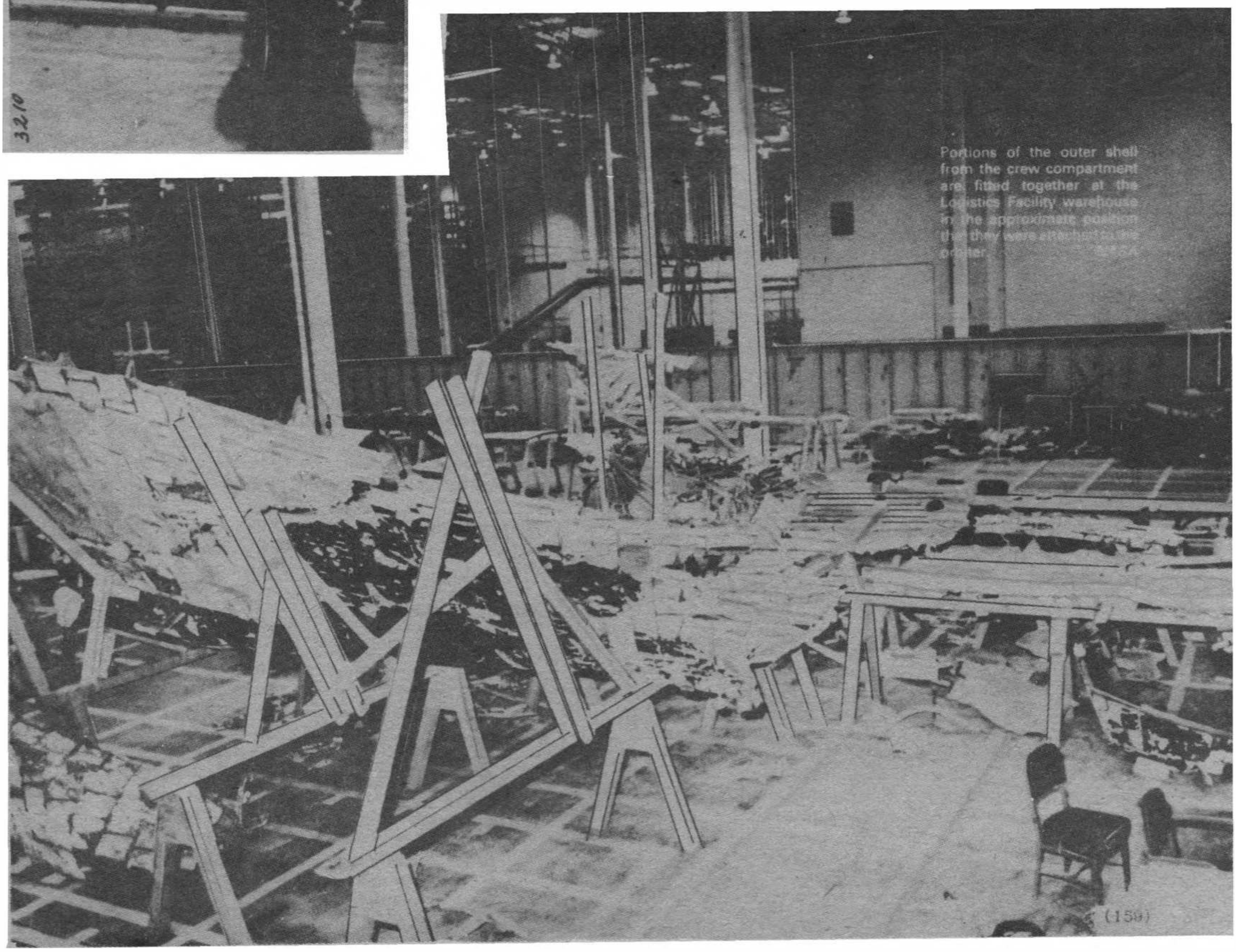
The astronauts probably activated the air packs instinctively after oxygen flow to the Launch and Entry Helmets was cut off during structural breakup. The nearly depleted PEAP of Mike Smith must have been switched on by either Judith Resnick or Ellison Onizuka from the rear cockpit because the air packs for the pilots are mounted on the back of their seats. Although pathologists were not able to determine the astronauts' condition after the explosion, it is possible that the crew were still alive, but unconscious, when the cabin struck the water 165 seconds later.

Conclusion

The $100 million Challenger salvage operation officially concluded on August 28, 1986. One hundred and eleven tonnes of wreckage was ultimately recovered, representing about 50 per cent of the SRB's, 50 per cent of the External Tank and 35 per cent of the orbiter. Significant fractions of the TDRS and Spartan-Halley payloads were also retrieved for engineering analysis.

Permanent memorials to the "Challenger Seven" are being established in several aerospace museums in America using mission emblems and other momentoes retrieved from the sunken crew module. NASA entombed the Challenger debris in two abandoned Minuteman silos (Complex 30 and 31) at Cape Canaveral earlier this year.





Portions of the outer shell from the crew compartment are fitted together at the Logistics Facility warehouse in the approximate position that they were attached to the orbiter. NASA

Synopsis of the Nomenclature of the Fixed Stars

H. Werner and F. Schneidler, Wissenschaftliche Verlagsgesellschaft POB 40, D-7000 Stuttgart 1, W-Germany. 510 pp, 1986, D.M. 138.

From antiquity groups of stars formed into constellations have provided essential aids to orientation in the sky. However, the number and kind of constellations have not been the same all the time. Those known to the Greek astronomers, as listed in Ptolemy's Almagest, were really the product of a long historical line of development and, in modern times, further constellations were added by European astronomers, even if not always generally recognised. During the age of discovery, the stars of the southern skies were discovered and divided into constellations as well, with the result that, today, there are 88 recognised constellations.

Up to now there has been no survey in astronomy which enabled easy comparison to be made between the notions of earlier times about what stars belonged to which constellations and as they now stand. This synopsis fills that need. Basically, it reaches down to stars of magnitude five though fainter stars are included where necessary. It includes the different styles of nomenclature taken from 40 major star catalogues, including Ptomely's system of numbering the stars, the Greek letters used by Bayer and the numbering introduced by Flamsteed and added to up to the present time. Approximately 100,000 numbers, symbols and letters are thus covered.

The book, printed in English and German, begins with introductory text describing the constellations and designations used for individual stars, before continuing with descriptions of all the important catalogues upon which it has been based.

This is followed by the main text which deals with each constellation in turn, in alphabetical order, beginning with a description of the meaning and origin of each, its brightest stars, the area of sky occupied etc., and including a map for easy identification. Tabular data is included for every star, together with identifying letters or numbers used in earlier catalogues.

The result emerges as a very useful and tidy presentation, though it must not be assumed that every star indicated in all the earlier catalogues has thereby been identified. In the past, other observers have attempted to provide a similar means of ready reference, not least as in the Society's copy of Bayer's Atlas, but have foundered over lists of stars which cannot now be identified or which could be duplicates, misobservations, etc.

This work, a labour of 20 years standing, must surely represent the greatest degree of accuracy now possible.

Dark Companions of Stars

P. van de Kamp. D. Reidel Publishing Co., Spuiboulevard 50, P.O.Box 989, 3300 AZ Dordrecht, The Netherlands. 1986, 114pp, £30.25.

This is a text re-printed with hard covers from *Space Science Reviews*. It consists of two parts. The first surveys our local cosmic neighbourhood, giving a general description of its stellar population with emphasis on the photographic astrometric survey of the lower end of the Main Sequence group in a quest for information about unseen companions, particularly dark dwarfs. The second part deals with probable unseen stars and planets.

Quasars

Eds G. Swarup & V.K. Kapahi, D. Reidel Publishing Co., Spuilboulevard 50, P.O.Box 989/3300 AZ Dordrecht, The Netherlands. 1986, 605 pp, £74.00

Quasars were discovered by Maarten Schmidt in 1963 when he interpreted the optical spectrum of the stellar object identified as radio source 3C 273 as indicating, what was then, an unusually high redshift. This discovery introduced severe theoretical problems in attempting to understand the tremendous energy released in such a small volume of space.

The quasar phenomenon has since come to be recognised as an extreme example of a range of violent activity which occur in active galactic nuclei, with an energy source believed to lie in the gravitational field associated with massive objects. Even though many spectacular observational and theoretical results have been obtained and some 3,000 quasars catalogued through radio, optical and X-ray means, the quasar phenomenon is still far from understood.

The wide range of such problems is covered in this volume. It includes studies of the continuum properties in quasars, their structure and morphology in the radio, IR, optical, UV and X-ray regions of the spectrum, emission and absorption line studies, nature and models of their prime movers, cosmological evolution and the implications stemming from this, besides studies of clustering and pairing – as well as their use as probes of the intervening medium and dark matter in the Universe.

As this volume shows, quasars have provided a valuable insight into the large-scale structure of the Universe and are likely to remain at the forefront of research in extragalactic astronomy for many years to come.

Atlas of Galactic Nebulae, Part 1.

T. Neckel & H.Vehrenberg, Treugesell-Verlang Dr. Vehrenberg KG, Schillerstrasse 17, D-4000 Dusseldorf 1, Germany. 1985, 128 plates and 50pp booklet. Loose-leaf binding.$78.

This, first of three volumes to appear over an 18 month period, surveys the sky from R.A. 0^h to 12^h and Dec +90° to -33° for the epochs 1950 and 2000. Within this framework, 435 diffuse nebulae appear and are illustrated or described. Diffuse nebulae are those without regular form or shape and which embody clouds of stars and gas, either indicating star formation or the remnants of stars in the final processes of decay. Many are well-known objects of considerable beauty and intrinsic interest, making the compilation one of great value. By definition, all planetary nebulae and galaxies within this band have been excluded.

Dynamical Spacetimes and Numerical Relativity

Ed. J.M. Centrella. Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 465pp, £30.

The coincidence of the great current interest in building gravitational-wave detectors and new developments in supercomputers make this comprehensive account of numerical simulations of spacetimes containing strong gravitational fields, based on a workshop held in October 1985, most timely.

Topics examined include the gravitational collapse of stars and the resulting production of gravity waves, together with new analytic calculations that blend synergistically with the numerical models. A special feature of the volume is the emphasis placed on test-bed calculations to guarantee the accuracy and reliability of numerical codes.

The book provides a guide to the state of the art in numerical modelling of general relativistic systems. Graduate students and professional researchers in general relativity, astrophysics and cosmology wishing to keep pace with both the achievements and the problems in this rapidly developing are sure to find it most valuable.

Aerospace Crew Station Design

Ed. G.P. Carr & M.D. Montemerlo. Elsevier Science Publishers, PO Box 1991, 1000 BZ Amsterdam, The Netherlands. 1984, 346pp, US $58.

This volume presents the proceedings of a course held in Italy in October 1983, the first of a series of bi-annual meetings designed to provide an international forum for the exchange of concepts and techniques in the design of aircraft and spacecraft crew stations.

The subject has many other definitions e.g. human factors engineering, the man-machine interface and biomechanics - but they all involve design considerations where an interaction takes place between humans and machines or systems.

A total of 14 papers are included, of which six readily relate to space, the remainder being concerned with such topics as aircraft cockpits for pilots. In each of the four main sections, relating either to aircraft or spacecraft, there is an opening historical paper which describes crew stations of the past and evolution of designs up to the present day, with some consideration of future needs.

Optimal Spacecraft Rotational Manoeuvres

Eds. J.L. Junkins & J.D. Turner, Elsevier Publishing Co., P.O. Box 1663, Grand Central Station, New York, NY 10163, USA. 1986, 516 pp, $109.25.

This monograph is directed toward solving a family of problems which arise in manoeuvering modern spacecraft, ranging from fundamental developments in analytical dynamics and optimal control to a significant collection of example applications. The primary emphasis is upon the most central analytical and numerical methods for determining the optimal rotational manoeuvres of spacecraft. Large angle nonlinear and large rotational manoeuvres of flexible vehicles with sumultaneous vibration suppression/arrest are also considered.

The book provides much new material which should be of great interest to those working in the general areas of spacecraft technology, applied mathematics, optimal control theory, and numerical optimisation. Chapter 11, in particular, presents new information useful for terminal control and tracking manoeuvres.

Astronomical Observations – An Optical Perspective

G. Walker, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1987, 347pp, £40.00 hardback, £15.00 paperback.

All the information we have about the Universe beyond the Solar System, so far, is based on data received via electromagnetic radiation and cosmic waves.

This book provides a comprehensive account of current observational techniques used in astronomy to detect and interpret data coming from such sources. Although particular emphasis is placed on optical astronomy, the volume gives a complete survey of basic observing techniques available to astronomers for all wavelengths of the electromagnetic spectrum.

The various types and sources of stellar electromagnetic radiation are covered as well as the range of instruments available to observe them. Some particular topics include the construction of sensitive low-noise detectors, preservation of image quality and limits to measurement precision.

This work is particularly timely because, although astronomers nowadays have access to a wide range of telescopes both on the ground and in orbit, there is an increasing demand for observing time which makes it essential to know the principles and limitations of instruments and techniques well beforehand.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

CORRESPONDENCE

Influencing Public Opinion

Sir, I suspect the Saturday Column by Christopher Booker (*Daily Telegraph*, February 28,1987) on the 1969 Moon landing in which he asks, "Was that 'gigantic leap' really heroic or just an act of self-deception" to be indicative of the way in which an increasing number of people think.

What concerns me is the paragraph:

"As we ourselves look back on the moonshot nearly 20 years later, we wonder what it really achieved for the human race? Did it bring us any closer to some ultimate truth or to any greater sense of humanity. In many ways it seems to have been one of the greatest and most baffling dead-ends humanity has ever reached in our long emergence from an unconscious state of nature."

I am sure that many people will wish to know if the allegations made in the article against Werner von Braun have any substance.

TONY DEVEREUX
Essex

Ed. *'Knocking' space goes on in the non-technical media world-wide. Readers are urged to respond promptly by writing to the publications concerned pointing out the importance of the long-term benefits of space.*

Canada in Space

Sir, Many thanks for sending me the January issue of your very handsome magazine. I appreciate the faithful portrayal of Spar programmes – it serves well both our own interests and those of international cooperation.

CHRISTOPHER G. TRUMP
Vice President
Spar Aerospace Ltd.

Soyuz 4/Soyuz 5 Launch Times

Sir, P.S. Clark's analysis of the launch times of the Soyuz 4 and Soyuz 5 spacecraft is undoubtedly correct, the nine minute differences being due to the announcement of injection times. This point was resolved many years ago at the request of the late Dr. Charles S. Sheldon and launch times of 07.30 and 07.04 GMT respectively are quoted in *Soviet Space Programs: 1976-80,* (Part 2, Table 15, p.662). Mission durations are given as 71 hrs 21 min and 72 hrs 54 min respectively; the values later quoted in the encyclopedia edited by V.L. Glushko.

G.E. PERRY M.B.E.
The Kettering Group
Northants

Lifeboat in Space

Sir, In the event of structural failure or unforeseen accident at a space station, an escape craft is needed which has the capacity to sustain life for up to six crew members until a rescue craft arrives. The escape craft could be one of the space station's sections that is set aside as a rest area and fitted with fuel tanks and water supplies etc.

Additionally, this section of the space station could have a built-in orbital manoeuvering system (OMS) and its own thermal protection. It could then disengage itself from the rest of the structure and re-enter the Earth's atmosphere.

MIKE BROWN
Birmingham

Sampling Venus

Sir, The article 'Sampling Venus' (***Spaceflight***, February 1987, p.78) explains in detail six phases of collecting samples from the surface of Venus, and concludes: "After rendezvous with the VOV, Phase six consists of the flight back to Earth. The samples are placed in a canister which describes a highly elliptical orbit about Earth and is retrieved by an orbital manoeuvring vehicle."

There is no mention in Phase six about precautions taken when bringing samples to Earth. What safety measures are taken to protect Earth from accidental introduction of living organisms from space? If scientists do take the matter seriously why is it not made clear in the article?

A paragraph in the booklet "Space Works" (1985, p.58) by Stuart Malin and Carole Stott states: "If Mars had a wetter past with a thicker atmosphere could it not also have developed life? Probably not intelligent life as we know it, but primitive micro-organisms that today lie dormant in Mars' billion-year long ice age waiting to be re-activated when the moisture returns.

"To answer these questions and many others, two spacecraft called Viking 1 and 2 landed on Mars in 1976 and placed a scoop of soil into a tiny chemical laboratory for analysis. The results were inconclusive and tantalising. There is probably no primitive form of life in the red sands of Mars, but we are not sure and will have to go back again and re-ask the question."

We all seem so eager to discover living organisms on other planets but if and when we do are we really aware of the true implications of such a discovery?

With so much activity by a variety of countries in the conquest of near space it is time to think again on the dangers to health when bringing back disused satellites and samples from planets. After all, scientists have to admit that they do not really know what they are dealing with when it comes to the possibility of living organisms in space. The first discovery could be too late.

MISS J. CRAMPHAM
London

Ed. *A response to the point raised by Miss Crampham has been provided by Dr. William McLaughlin as follows:*

Reader Crampham quite correctly points out the necessity for careful treatment of any extraterrestrial samples that might be returned to Earth. During the Apollo lunar landing programme, extensive precautions were taken to insure against the possibility of contamination – recall the procedures for quarantine of returning astronauts. In fact, NASA missions are evaluated in detail, prior to launch, with regard to all relevant environmental impacts.

However, the Venus Sample Return that was described in the February issue was, as indicated in the article, a conceptual study. In all likelihood the scenario, as described, will never be flown. The point of such studies is to present a tableau of ideas that could eventually evolve into a mission plan after exposure to the critical judgment of the astronautical community.

Thus, important items such as cost, launch vehicle, launch date, and environmental considerations were not treated; the state of development of the study would not support any meaningful analysis in these areas. And, indeed, no useful purpose would be served by evaluating enabling factors prior to the commitment to undertake a mission.

It is encouraging that the exploration of space is such a positive force in the building of a civilisation on Earth. In contrast to many organised human activities it is neither banal nor pernicious. Nonetheless, Miss Crampham properly reminds us that there is a place for caution in protecting our fragile niche in the Universe – even as we explore beyond it.

CORRESPONDENCE

SETI

Sir, In ***Spaceflight***, Sept./Oct. 1986, p.353, E.J. Coffey calls the "Fermi Paradox" "the central question of SETI". I don't even think that Fermi's *question*: "Where are they?" is a paradox. Although many consider interstellar travel to be human destiny, we have yet to discover a way to make interstellar travel economically feasible. Until we do where is the paradox?

Coffey feels that the answer "lies with the evolutionary biologists' objections to SETI, which have been so persistently ignored". The two allegations made in this sentence: that evolutionary biologists, as a class, object to SETI and that we SETI buffs ignore their objections is not true. All the evolutionary biologists I know, and this includes such notables as David Raup and Steven Jay Gould, are quite happy with SETI and with the concept of statistically similar evolution on similar worlds.

The grand principle we persistently ignore seems to be the rather obvious one that "structure" and "function" are not independent or, as the architect Louis Sullivan used to say "form follows function". This is often true in living things when the function is the control or utilisation of certain physical forces. The similar streamlining of fish, cetaceae, and birds is a familiar example. But in other instances we admire the diversity of solutions to a common problem. Consider the eyes of bees and vertebrates. Or consider two solutions to breathing: the leaves of trees and our own lungs.

Coffey seems to feel that the principle that similar function implies similar form is so strong as to apply to intelligence. To him, all animal intelligence is different (since their forms are) and "Since 'humanoid' intelligence logically implies 'humanoid' behaviour, one would not expect 'humanoid' intelligence to be coupled with an alien body". And, believe me, the body will be alien!

"The extraterrestrials, if they exist, . . will be unlike anything we have ever known: neither flowering plants, vertebrates, arthropods, [n]or any other terrestrial group we are familiar with . . ". Why is he so sure? I can accept the statement as a possibility but not as a certainty – I do know that much about them. It seems to me that to populate the 10^{10} good earths of the Galaxy in such a way that no two had any similar taxonomic groups would be almost impossible.

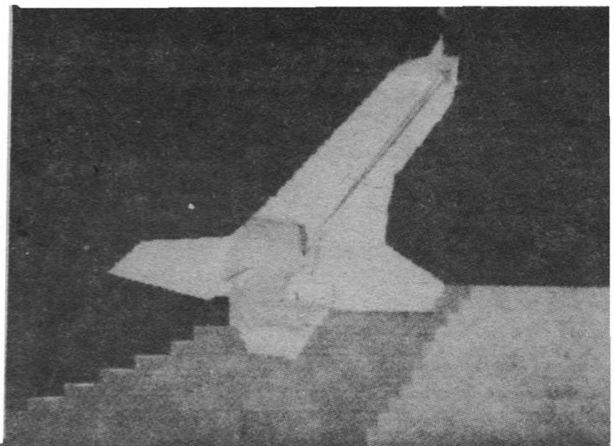
Nevertheless, the argument goes: no humanoids, no humanoid intelligence and no humanoid intelligence no interstellar space flight. Since humanoid intelligence has not yet produced interstellar space flight, I find this an illogical and unconvincing argument. Why cannot an octopus, who today can learn without instruction how to open a screw top jar, have descendants that fly spacecraft?

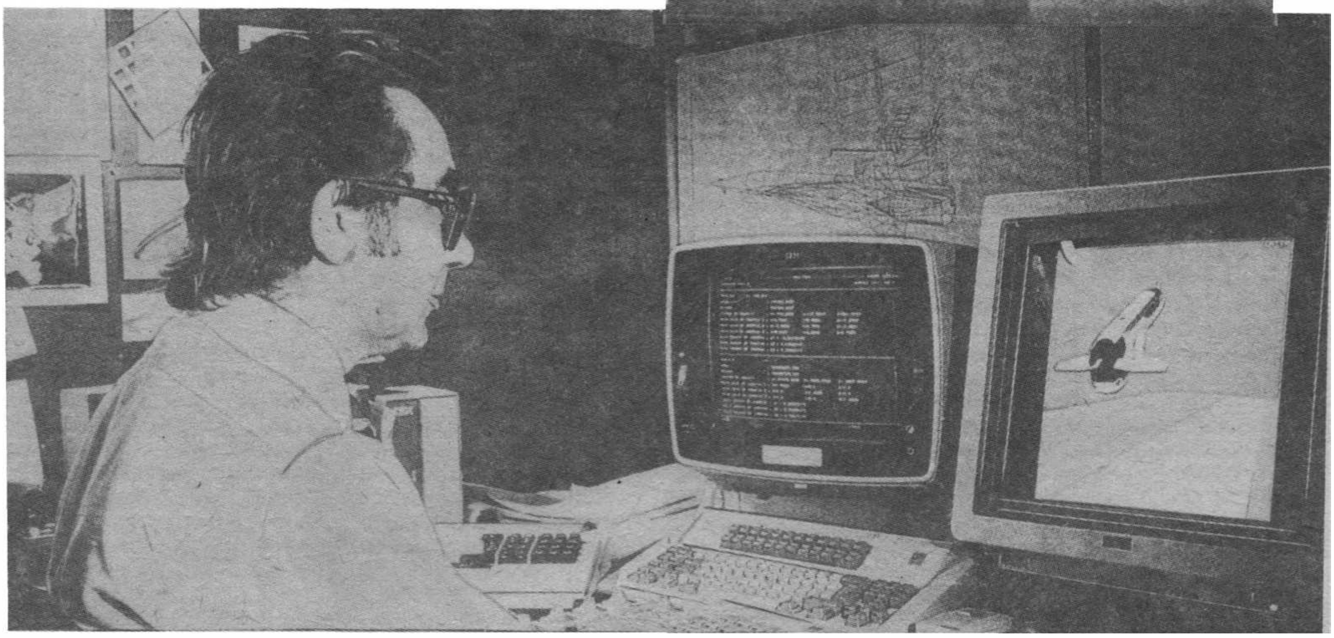
BERNARD M. OLIVER
Chief, SETI Program Office
NASA

Hotol Simulation

Sir, I would like to congratulate you for making ***Spaceflight*** such a superb (and my favourite) magazine. I am in my third year of Physics at the University of Leuven and I have access to the University's main IBM computer. The picture on page 6 of the January 1987 issue showing a Hotol simulation stimulated me to generate a number of simulations myself. One of them is almost exactly the same as the one shown on the programmer's terminal and I enclose a copy. On the screen the effect is better, with more colour and straight lines that are really straight. The reason for this is that we have to use a printer instead of a plotter which has "only" four colours and problems arise when it has to join two coloured surfaces.

KRISTIAAN TEMST
Meerbeok, Belgium





Soviet Space Programme

Sir, Several points have been raised recently by correspondents on different aspects of the Soviet space programme (***Spaceflight***, March 1987, pp.92-93). While I cannot necessarily provide the answers, I can add one or two snippets of information which might help.

First, on the subject of the launch times of Soyuz 4 and Soyuz 5, it is true that supposedly "incorrect" times were published in 1969. As Phillip Clark points out, orbital injection was quoted rather than launch, the two events being separated by about 9.5 minutes. The discrepancy was noted soon after the event, but I am not aware of anyone specifically pointing it out in print at the time.

A 1984 report to the US Senate, "Soviet Space Programs: 1976-80", lists, in tables on pages 657 and 662, precise times of both launches and landings, and uses a Soviet booklet published in 1982 as a source for mission durations. Apart from the confusion over launch and injection times, the 1969 errors (if they merit that strong a description) amount to no more than minor timekeeping inaccuracies, and can be attributed in part to rounding up or down to the nearest minute. Interestingly, a footnote to one of the Senate report tables points out that variations can be found in times relating to American manned space missions, brought about by published figures emanating from different NASA offices!

For information, here are the Soyuz 4 and 5 mission events (in GMT) as contained in the Senate report. As far as I can tell, the launch and landing times are borne out by NORAD's orbital data. In all cases, times appear to have been rounded down to the nearest minute:

	Launch	Landing	Mission Duration
Soyuz 4	14 Jan, 0730	17 Jan, 0651	2d 23h 21m
Soyuz 5	15 Jan, 0704	18 Jan, 0758	3d 0h 54m

A parallel occurred later in 1969, when the mission start time given for Soyuz 8 failed to fit in with those of Soyuz 6 and 7, its companions. The wording of the official TASS news release gave a hint when it said "... put into orbit ...", implying orbital injection rather than launch. I also have a copy of a launch announcement, in English, for Soyuz 4 which contains the phrase "... launched ... into orbit ...", possibly a mild mis-translation of the original Russian. The Soyuz 8 discrepancy was documented in 1970 when we published, from Kettering, our log of Soyuz 6/7/8 radio observations. We pointed out, and explained, the apparent anomaly in the Soyuz 8 time.

To change the subject and pick up David Anderman's (***Spaceflight***, January 1987, p.16) and Saunders Kramer's (***Spaceflight***, March 1987, p.92) discussion about the Meteor satellites' launch vehicles, the "Two Line Orbital Elements" provide a useful clue.

In 1984/5, the programme changed from using orbits near 81 degrees inclination to orbits at 82.5 degrees. Information derived from the Twolines indicates a corresponding change in launch technique from a direct ascent trajectory to the use of an elliptical transfer orbit. It has a perigee around 100 kilometres, and the upper stage rocket fires at first apogee to circularise at the operational height. If, as Saunders Kramer surmises, the F-2 (or any other new launch vehicle) is the current launcher, then it probably took over from the A-vehicle at that time. Originally, use of the A-1 was dictated by it being the smallest rocket with sufficient lifting capacity at the time the Meteor programme was conceived.

Glushko's rocket mass total up to 1980 is consistent with the eight low orbit Meteors having used the 1.4 tonne Vostok stage, and the 28 high orbit and retrograde Meteors the 2.3 tonne Soyuz version (total – 75.6 tonnes against his 75.3 tonnes). The 1984 figure makes sense if Glushko revised his formula on the basis of the four satellites in retrograde orbit being A-1 (Vostok) launched. Using 1.4 tonnes (12 missions) and 2.3 tonnes (30 missions), we arrive at 85.8 tonnes. Glushko gives 84.2 tonnes, but the launch record includes two supposed F-2 upper stages. If they weigh in at around 1.5 tonnes each, then the remaining difference is explained.

As to the relative orbit heights reached by the satellite and its final rocket stage, differences will presumably occur due to venting (as explained by Mr Kramer), and the separation mechanism employed for a particular satellite type. Variations then become specific to the satellite and cannot be taken as a reliable guide to the kind of rocket stage involved.

ROBERT CHRISTY
Lincoln, England

Launch Times

Sir, Phillip Clark's calculations for the launch times of Soyuz 4 and 5 in 1969 (***Spaceflight***, March 1987, p.93) are supported by at least one Soviet source [1]. This book gives a Soyuz 4 launch time of 1030 MT on January 14. This is 0730 GMT and agrees with Mr. Clark's calculation of 0729 (plus or minus a minute).

The Soyuz 5 launch time is given as 1005 MT (0705 GMT). This is exactly the same as Mr. Clark's prediction. Interestingly the Soviet book also provides the time Soyuz 5 entered orbit – 0714 GMT. This confirms the theory that earlier Soviet announcements gave the orbital injection time rather than launch.

Mission durations then become:

Soyuz 4: 2 days 23 hours 23 minutes.
Soyuz 5: 3 days 0 hours 55 minutes.

The same confusion seems to exist in the cases of at least two other Soviet flights.

Soyuz 8 is usually quoted as being launched at 1029 GMT on October 13, 1969 with a flight time of 4 days 22 hours 41 minutes. The reference Soviet book gives a launch time of 1019 GMT with the orbital insertion actually occurring at 1029 GMT. The flight time is then 4 days 22 hours and 51 minutes, ten minutes longer than previously quoted. This flight duration has been quoted in other sources recently but I have not seen the launch time of 1019 GMT published elsewhere.

I am not aware of a launch time being quoted anywhere for Soyuz 14 in 1974. The Soviets have quoted an orbital insertion time of 1851 GMT which means a launch at about 1842 GMT, and mission duration of about 15 days 17 hours and 39 minutes instead of the usually quoted 15 days 17 hours 30 minutes.

ALAN LAWRIE
Hitchin, Herts

Reference
1 Sons of the Blue Planet, Lebedev, Lukyanov, Romanov, 1971 (translation 1973)

British Involvement

Sir, With reference to your article on the Comet Rendezvous and Asteroid Flyby mission (***Spaceflight***, February 1987, p.81) there will be some British involvement in the mission.

The Mullard Space Science Laboratory (MSSL) of University College London will be involved in the design and manufacturing stage of the Plasma Analyzer being built by Southwest Research Institute. The Space Plasma Physics group under Dr. A.D. Johnstone, who is a co-investigator, will also participate in the data analysis.

Dr. MARK SMITH
Mullard Space Science Laboratory
University College London

CORRESPONDENCE

Crew Escape System: Proposal OK'd

Sir, J.S. Anderson, ***Spaceflight***, February 1987, invites comments on his suggestion to fit small solid rocket boosters to the wings of the Shuttle Orbiter to give the craft sufficient "pull" to escape the External Tank assembly in event of launch malfunction.

One's first reaction to such revolutionary proposals is to examine all aspects and pick as many technological holes in it as can be found, with (human nature being what it is) a measure of poorly concealed condescension.

However, the more I examine this particular notion, the more difficult it is to come up with any technical objection which carries real stopping-power. On close examination, all the major stumbling blocks that initially spring to mind fade to relatively minor points, all of which appear to be surmountable.

For instance: sufficient vertical pull to lift the orbiter rapidly from the external tank would, if applied from wing rockets, tear the wings off: but; most of the thrust, it turns out, would tend to be horizontal, not vertical, allowing the orbiter to "loop" upside-down and plummet into a glidepath. Then: the extra weight of such wing rockets would reduce the available payload weight: but; the rockets would be ejected around SRB separation and prior to this point launch mass is not quite so critical, especially when weighed against safety factors. And so on.

In short, every argument I can conjure up against this idea can be reduced to the level of a (comparatively) petty alteration or adjustment. Although I suppose it is unlikely to be adopted, it would on the face of it appear to be a plausible suggestion, and I take my hat off to it. Could anyone take it further?

P.W. MILLS
Chatham, Kent

European Hotol Funding

Sir, Having read the latest details published on Hotol (***Spaceflight***, Jan. 87, p.4), one cannot but admire the concept and the ingenious RB 545 engine.

If Europe does not fund the Hotol project as soon as possible, it could lose ground against ambitious projects on air breathing engines being undertaken by the US and probably the USSR for space launchers to be used after the year 2000.

M.Q. HASSAN
Baghdad, Iraq

Mir Orbital Manoeuvres

Sir, Now that permanent manning of the Soviet Mir space station is underway and additional modules are due to be attached, one puzzling question springs to mind. Once the large astrophysics module is attached to one of the four radial docking ports, the centre of mass of the Mir complex will be shifted away from the axis. Thus, in order to carry out orbital manoeuvres (e.g. orbit raising which will eventually become necessary), the Mir or Progress engines must be gimballed so that their thrust vector passes through the centre of mass in order to avoid inducing unwanted rotations.

Are the Soviet craft capable of gimballing their engines, and if not, how will manoeuvres be executed without using huge quantities of attitude control propellant? The simple answer might be to attach another large module on the opposite docking port – perhaps expansion of the Mir station will be more rapid that we have so far thought.

RALPH LORENZ
Solihull, West Midlands

Crew Escape System: Proposal KO'd

Sir, I write in response to J.S. Anderson's letter published in ***Spaceflight***, February 1987, concerning wing mounted rocket pods to be used to blast the orbiter clear of the rest of the stack in the case of emergency during the first phase of the launch.

I think the main shortfall in this suggestion is that there is a good chance that the orbiter would be over-stressed during this manoeuvre both aerodynamically and by the deceleration effect caused by the sudden separation from the solid rocket boosters (SRB) combined 5.8 million pound thrust. This would surely cause break-up of the vehicle in much the same way as 51L. The payload bay would probably be thrown into chaos with structural breakages similar to those expected if an orbiter ditched (i.e. failure of the payload retention brackets etc.) causing the payload to shoot forward into the crew compartment.

Unfortunately, I think that the first phase of an STS mission is always going to have a high element of risk and safety can only be improved, really, by increased SRB reliability

M.D. KINGSLEY-JONES
Maidenhead, Berks

Space Station Backing

Sir, After watching a "Newsnight" piece on the delay of Britain's contribution to the European section of the new space station project, I was sufficiently moved to write to the Minister responsible – Mr. Geoffrey Pattie – to remind him of the benefits to be gained from Britain's participation in this project. I hope that this may have at least a minimal effect on future decisions.

P.W. DAVEY
Dorset

Spacelab Demise

Sir, With publication of the new NASA Space Shuttle flight manifest (***Spaceflight***, November 1986, p.378), the demise of the European Spacelab programme has been demonstrated, yet there seems to have been little or no reaction from the space community or in the media.

It is true that all of the Spacelab missions using the Long Module that had flight assignments before the Challenger accident have been retained on the new manifest, but where are the new starts and missions just in the planning stage when the programme ground to a halt?

After 1991 there is not a single Spacelab mission listed in the flight requirements section of the new manifest and only a precious few Spacelab-type missions using pallet combinations are in evidence. Will new starts appear in the middle of the decade, or has Spacelab been effectively written off, rendered redundant by the coming of the Columbus facility on the (troubled) Space Station project?

To me space science investigations have always been among the most interesting missions of the Space Shuttle and it saddens me to see the apparent demise of space science as a priority in the Space Shuttle programme.

JOEL POWELL
Calgary, Canada

Spacelab is featured overleaf where we highlight the changing fortunes of Spacelab experimenters, brought about by the Challenger accident, and also report on recently released results obtained from the Spacelab 1 mission in 1983.

SPACELAB

Before and After Challenger

Spacelab was funded, developed and built by the European Space Agency (ESA) as part of a joint undertaking with the National Aeronautics and Space Administration (NASA). Its construction involved 50 industrial firms in ten European countries and was a major undertaking for the European space community. Operationally, Spacelab was intended to realise the dream of space scientists – to be able to go into space like astronauts and perform research that cannot be done on Earth.

Spacelab sits in the cargo bay of the Space Shuttle Orbiter and on reaching orbit it is exposed to space by opening the cargo bay doors. Its capabilities are those of an orbiting research centre. A pressurised laboratory contains computers, work benches and instrument racks for experiments, while outside platforms (pallets) carry telescopes, antennas and sensors for direct exposure to space.

Working in a shirt sleeve environment, Spacelab scientists can handle equipment, react to unexpected experimental conditions and make changes of plans in collaboration with investigators on the ground. The mission ends with the equipment being returned to Earth, where it can be refurbished for use on later flights.

Spacelab 1 mission was undertaken in November 1983 and that of Spacelab 2 in July 1985. Spacelab was also adopted as a major tool of the German space programme and the first German Spacelab D1 was flown in October 1985. All three flights were highly successful.

Then came the Challenger accident on January 28, 1986 and the postponement of further Shuttle flights. The opportunity to frequently refly Spacelab instruments disappeared overnight and with it the potential of Spacelab as a research tool. When Shuttle flights resume, several years will be required to clear the backlog of delayed flights during which only new payloads of high priority will be scheduled. For Spacelab there is no prospect of flights being scheduled at anything like the rate that investigators would need. Over $1 billion worth of Spacelab equipment and instrumentation will be underused over the next ten years.

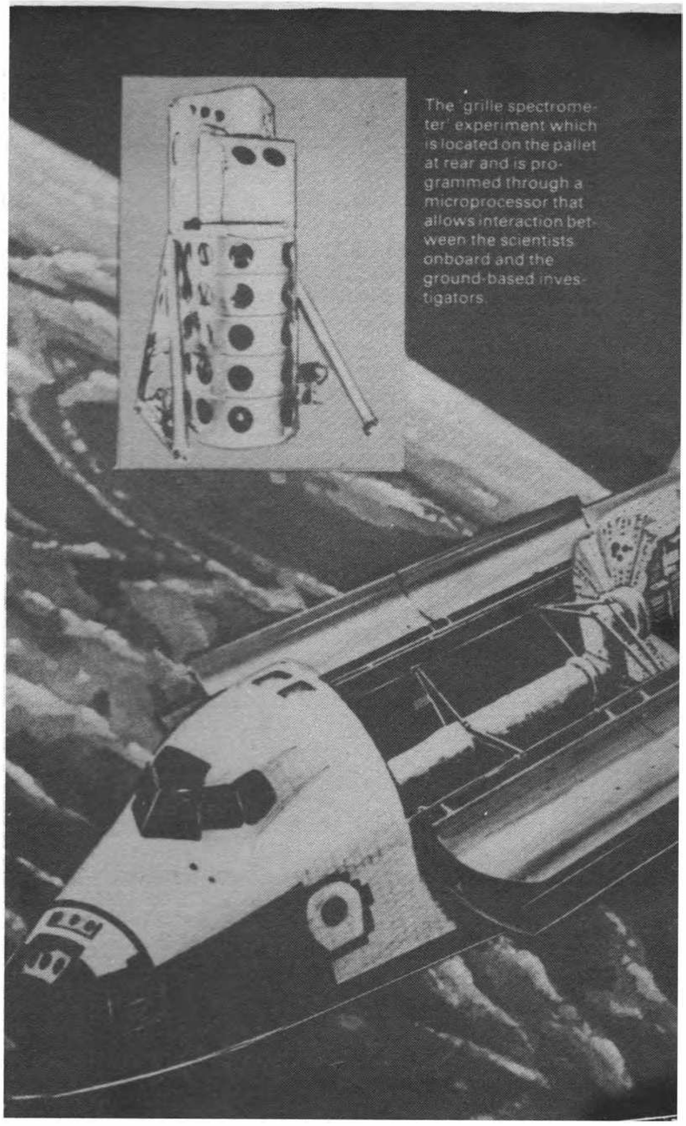
The situation is summarised by the following extract taken from 'Recommendations of SESAC on ensuring the near-term vitality of the Space and Earth Science Program'. This document was distributed in September 1986. SESAC is the Space and Earth Science Committee of the NASA Advisory Council (NAC):

"The Challenger accident also has raised significant near- and long-term questions concerning the viability and future direction of Shuttle/Spacelab and other attached payload programmes. Prior to January 28, 1986 there were firm plans for a major increase in these activities and the scientific community was looking forward to the increased opportunity for flight experiments which the Shuttle was going to provide. Now it appears that many of those opportunities will not be realised.

"Under the circumstances SESAC recommends that OSSA (Office of Space Science and Applications) carry out a thorough re-examination of its plans for the development and flight of Shuttle-based scientific instruments with a view towards realistically matching its planning with likely flight opportunities. The situation is serious and SESAC recognises, with great regret, that as a consequence of such an examination it may become necessary to substantially alter previous plans for such flight investigations. Resources made available from possible programme changes should be used to augment other areas of the space and Earth science research programme in an attempt to mitigate the effects of the Challenger disaster on the NASA scientific programme."

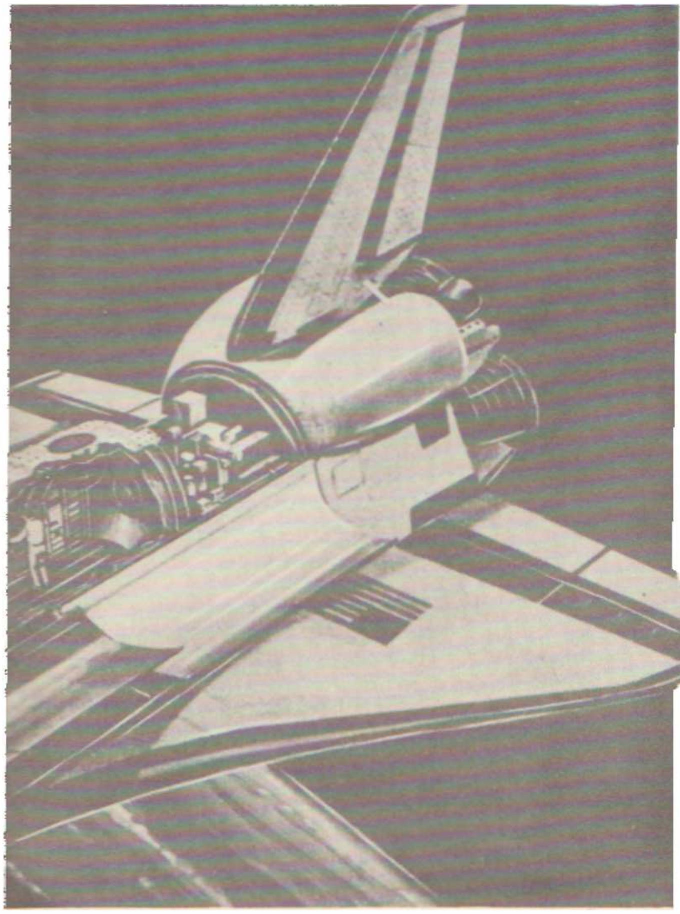
Some 120-140 scientific and technical personnel were involved in Spacelab 2 work and, without a follow-on programme for another five to ten years ahead, the research groups involved face a run-down with the inevitable dispersal of personnel.

The German space programme is also seriously affected. Following the German Spacelab D1 mission, a further three missions at roughly two-yearly intervals were planned before the launch of the international Space Station. On NASA's present schedule, the next mission, Spacelab D2, is to be in late 1991.



The 'grille spectrometer' experiment which is located on the pallet at rear and is programmed through a microprocessor that allows interaction between the scientists onboard and the ground-based investigators.

Scientists and members of the ground support team monitor a Spacelab mission from consoles in the Payload Operations Control Center at the Johnson Space Center in Houston.



Spacelab 1: Trace Atmospheric Gases

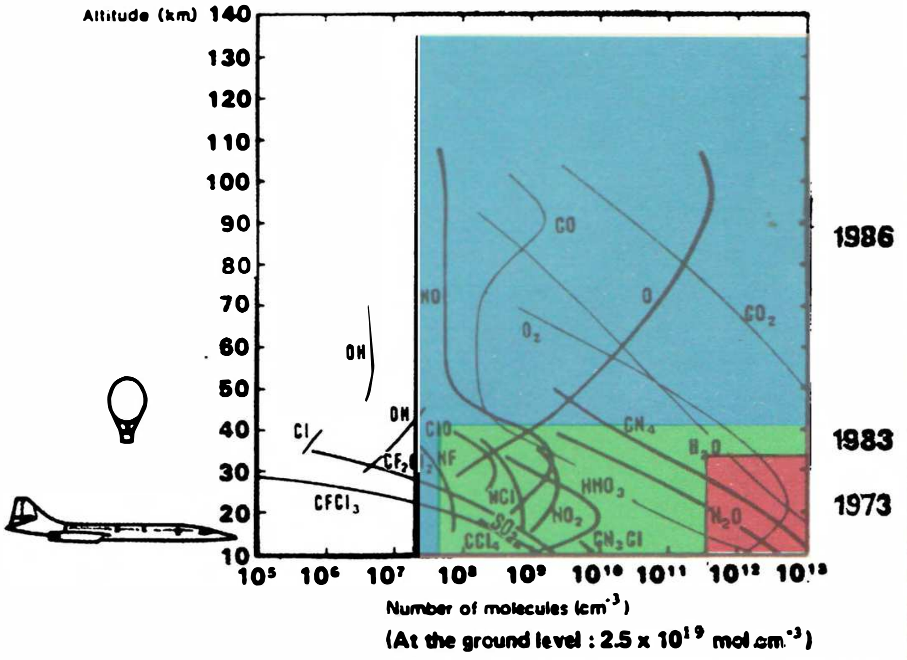
Spacelab 1 carried experiments for over 70 investigators. Among these was the 'Grille Spectrometer' of M. Ackerman, Belgium and A. Girard, France, which gave original results on the composition of the atmosphere. Vertical profiles of trace gases such as H_2O, CH_4, N_2O, NO, NO_2, CO, CO_2, were obtained for the first time between heights of 30 and 130 km.

The measuring technique is that of infrared spectroscopy to examine the atmosphere along the Earth's horizon or limb. The different gases are identified by their characteristic spectral signatures.

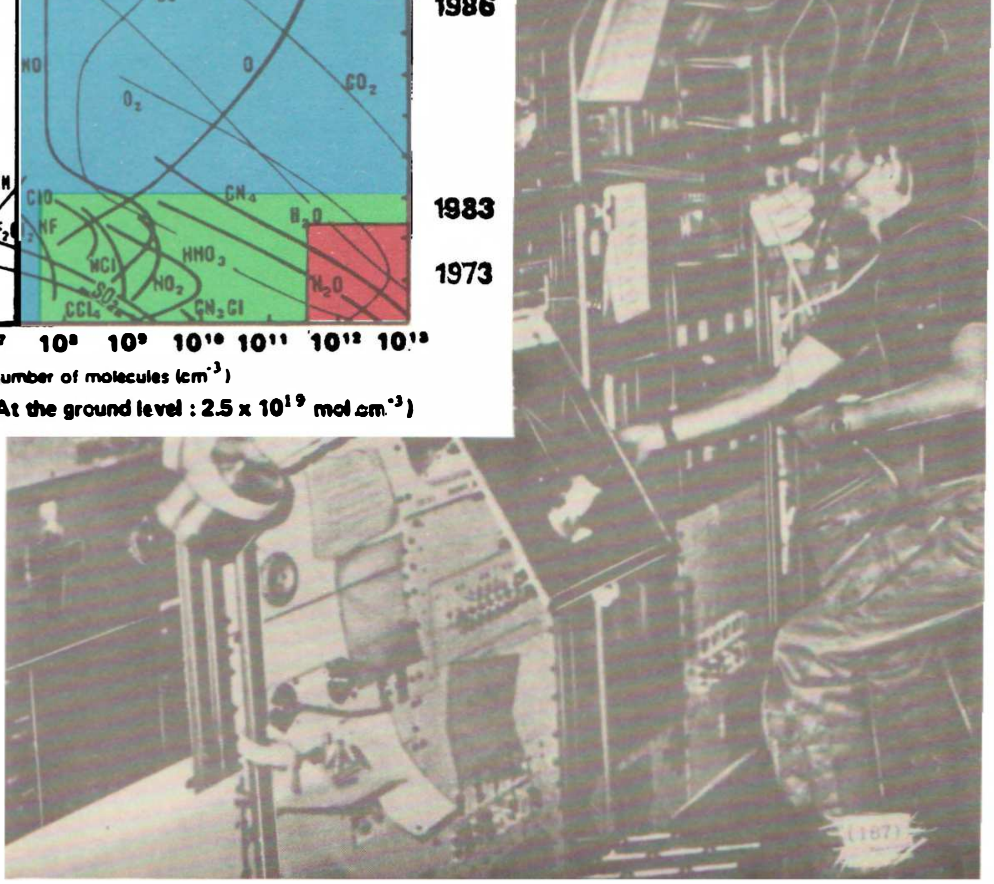
The equipment was prepared and installed on Spacelab by ONERA (Office National 'Etudes et de Recherches Aerospatiales). The operation followed similar experiments conducted by ONERA in 1973 with the same type of instrument on stratospheric balloons and aircraft, including the prototype Concorde.

The 1973 measurements were limited to heights up to 35 km as shown by the red triangle on the diagram (lower left). Repeat experiments in 1983 included at least ten new gases, including NO and NO_2, as shown by the green rectangle. Finally, the observations of the Franco-Belgium experiment on Spacelab 1 in 1983 were analysed and results up to 130 km for CO and CO_2 were published in 1986 (the blue rectangle).

Spacelab in the cargo bay of the Space Shuttle Orbiter showing the exposed instrument pallets and the pressurised laboratory module, which is connected to the orbiter's crew compartment by the crew access tunnel. The tunnel is the only major piece of Spacelab hardware made in the United States.



Vertical profiles (measured or modeled) of the gaseous trace gas components of the atmosphere.



Payload scientist Ulf Merbold at work during the Spacelab 1 mission.

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Spaceflight

The International Magazine of Space and Astronautics

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В связи с задержкой поступления из-за границы журнала "Космические полеты" № 3,4 высылаем Вам последующие номера.

Editor:
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27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

* * *

Spaceflight is distributed in the UK and overseas through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH, England. Tel. 0344 884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L. Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

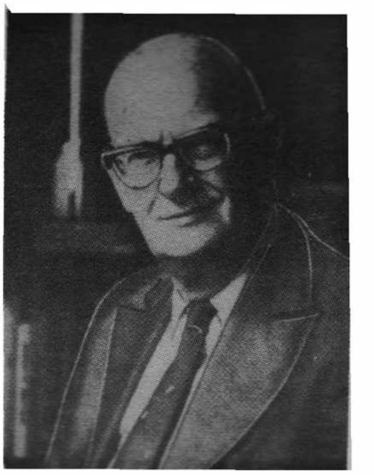
Vol. 29 No. 5 **May 1987**

Front Cover: High resolution images of the Earth's surface are now commercially available from the Spot 1 remote sensing satellite. Our cover depicts this satellite in its nearly circular orbit at a height of 850 km from which it provides a ground resolution of 10m (p.182).

Back Cover: A Chinese Long March 2 rocket is prepared for launch at the Shuang Cheng Xi launch site.

PEACESAT – Monitoring for Peace

by Arthur C. Clarke



Arthur C Clarke.

Four decades ago, during the closing months of the Second World War, two events occurred which completely changed the nature of warfare and, therefore, the course of history. The first was the advent of the V2 rocket, which gave mankind access to the new environment of space. The second was the dropping of the Atomic Bomb – the awful power of which, in only eight years was to be multiplied a thousand times. Within little more than a decade, the human race acquired weapons of infinite range and infinite destructiveness. In such a totally new situation, much of the wisdom of the past became folly.

But could one, as President Reagan wistfully hoped in his famous "Star Wars" speech of March 23, 1983 make these frightful weapons 'impotent'? The name 'Star Wars' has distorted the Strategic Defense Initiative's public image. In particular, it has focussed attention on orbiting fortresses using laser beams to zap ICBM's as they rise out of their silos – or, if they miss the first time, catching the warheads before they can re-enter the atmosphere.

I don't think many nations would be too happy to have such a threat passing overhead every few hours. So it seems rather unlikely that even a superpower would be allowed to build orbital fortresses – because by the time they became feasible, *any* industralised nation could prevent their construction by anti-satellite missiles (ASATS), shrapnel and 'space-mines'. And, not least, by lasers on the ground, which would have none of the power and weight limitations of those hoisted into space. Any orbiting Maginot Line could be destroyed for a minute fraction of its cost.

The extreme vulnerability of space-based systems has been underlined by one of their most prestigious critics, Dr. Edward Teller:

> *"To destroy satellites in space is the least difficult military application of lasers. This is an important reason why pre-deployed battle stations in space are not apt to survive... The deployed defense can be attacked over many months, even years."*

It should also be pointed out that it will be decades before such stations – and indeed many of the more elaborate "Star War" systems, would be practicable. Even if we could build them now, the vehicles to carry them into space do not yet exist. It would take dozens – perhaps hundreds – of Shuttle flights to assemble a fair-sized 'space fortress'. Even before the Challenger disaster, it was realised that – despite all the brave claims to the contrary – the Space Shuttle was hopelessly uneconomic. Both the efficiency and the reliability of launch systems will have to be increased by at least one order of magnitude before really large payloads can be placed in orbit.

This single factor makes many of today's space-war scenarius completely academic. If it survives long enough to build the efficient, reusable vehicles which alone would make space-fortresses possible, humanity will be too civilised to need them.

"The reward might be nothing less than the salvation of mankind."

The real problem is not military hardware, but human software – though the right kind of hardware can certainly help. A stable peace will never be possible without mutual trust; without that, all agreements and treaties are worse than useless, because they obscure the real issues. The only road to lasting Peace is through Truth.

A classic example of this is the infamous 'missile gap' debate which dominated the Kennedy-Nixon campaign of 1960. After the initial shock of Sputnik, which opened the Space Age in October 1957, there was a tendency in the United States to exaggerate all Russian accomplishments in this area. Propagandists ably assisted by the US military-industrial complex claimed that the USSR was far in advance in the deployment of ICBM's – so the United States must start a crash programme to overcome this 'enormous' lead.

Satellite Reconnaisance

Well, the missile gap was a total illusion, destroyed when the new American reconnaissance satellites revealed the truth about Soviet rocket deployment. President Johnson later remarked that reconnaissance satellites had saved the United States many times the entire cost of the space programme by making it unnecessary to build the counterforce originally planned. I would like to quote his exact words, which should be inscribed in letters of gold above the doors of the Pentagon – and the Kremlin:

> "We were doing things we didn't need to do, we were building things we didn't need to build; *we were harbouring fears we didn't need to harbour.*" (my emphasis.)

You will not be surprised to learn that the USSR reacted with great indignation to the existence of American 'spy satellites' probing into its secrets. Indeed, in 1962 it proposed to the United Nations that they be banned. These protests suddenly stopped when its own reconnaissance satellites started orbiting that very same year, and now both sides recognise their value as stabilising agents. They make possible such arms control agreements as we do have, as is disclosed by the formula always used when referring to them: "National technical means of verification" (NTM).

Although none of the high-quality images made by these NTM's has ever been released, you cannot classify the laws of optics and photography is now a rather well-established art; so we know exactly what reconnaissance satellites can do. In daylight, under good conditions, they can show individual soldiers and the weapons they are carrying. Although they can be frustrated by cloud and darkness, radar-equipped satellites now exist that can overcome even these limitations.

So it is probably true to say that no large scale military preparations or activities can ever again escape surveillance – at least by nations with NTM's. At present this means the United States and the Soviet Union.

In 1978 the Government of France made a dramatic suggestion. It might be a good idea, President Giscard d'Estaing suggested, if there was an *International* body doing for the whole world what the Americans and Russians were selfishly doing for themselves. Such an International Monitoring Satellite Agency would verify arms control agreements, check border violations, and defuse crisis situations, by acting as a watchdog for the world.

Establishing what I like to call "PEACESATS" would present major

This article is an abridgement of the Nehru Memorial Address entitled 'Star Wars and Star Peace', presented in New Delhi, India on November 13, 1986.

political, administrative and financial challenges – but the rewards might be [illegible] the salvation of mankind.

[illegible] to monitor the [illegible] commentary [illegible] infra-red image of the [illegible] out a [illegible] to be the [illegible] carpark. As the Second World War amply proved, reconnaissance material is only as good as its interpreters; but the [illegible] are getting very good indeed at interpreting images from space after they have been skilfully massaged in their computers.

Peacesat Scenario

I would like you to consider the following scenario which has a great advantage that it could be realised not only without the co-operation of the nuclear powers but even in the teeth of their opposition.

An advanced Spot with a resolution of say one metre (compared with Spot's present 10 metres – and the 0.1 metre of a reconnaissance satellite under favourable conditions) is launched by a consortium of non-aligned countries, which makes its results available to everyone (probably but not necessarily, through the UN). Most forms of military secrecy would then become impossible, and charges of fraud and cheating could be scrutinised by the whole world. And although there would be many clandestine activities that the PEACESAT could not detect, its psychological impact would be enormous.

The countries sponsoring and building PEACESAT might be Japan (the only non-nuclear space power – not to mention the only target for nuclear bombs); Canada (already planning a very advanced survey satellite); Sweden, with its high technology and interest in peace. They could go it alone if they wished, but moral and financial support should be forthcoming from many non-aligned nations. Even the fanatically neutral Swiss might be induced to join such a project.

We would enter what has been aptly called an 'Age of Transparency'. Like most people, many nations would not like to live in glass houses. They may not realise the extent to which they are already doing this. Quite apart from the US, USSR – and Chinese – satellite operators with their rather restricted clientele, Spot is up there right now, churning out beautiful images of all terrestrial activities for anyone who will pay a dollar a square kilometre for them. As the Age of Transparancy dawns, political and military wisdom will lie in cooperating with the inevitable.

I would like to end with some words I was privileged to deliver in October 1984, at the space symposium arranged by the Pontifical Academy of Science. The meeting brought together experts on science, communications and weaponry. A few hundred metres from Michaelangelo's Creation of Adam, we were discussing how his descendants might save – or destroy – themselves:

During the last decade, something new has come into the world. Two dimensional communications networks are replacing vertical chains of command, in which orders moved downwards and only acknowledgements went upwards. We are witnessing the rise of the Global Family – or Tribe, if you like. Its electronically-linked members will be scattered across the face of the planet, and its loyalties and interests will transcend all the ancient frontiers.

Overleaf: An example of detail recorded by the Spot 1 satellite.

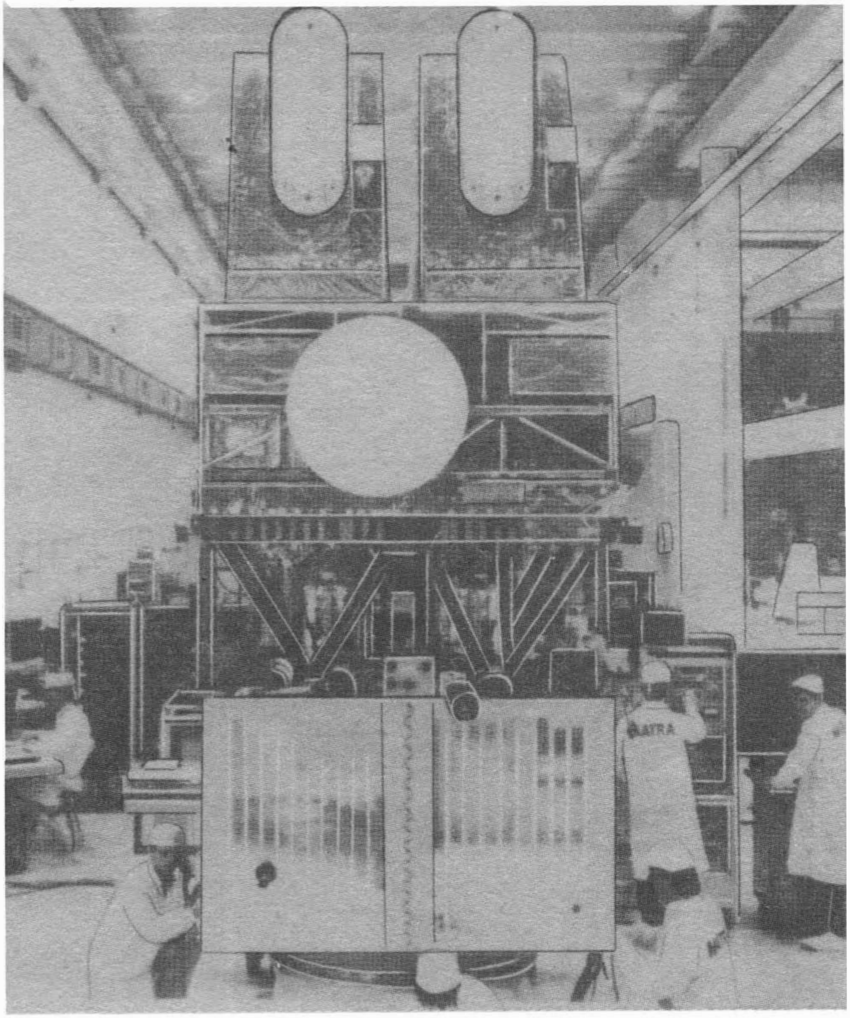
Those frontiers which are so conspicuously absent in the photographs from space: those frontiers which to call 'sacred' in the age of thermo-nuclear weapons is no longer patriotism – but blasphemy.

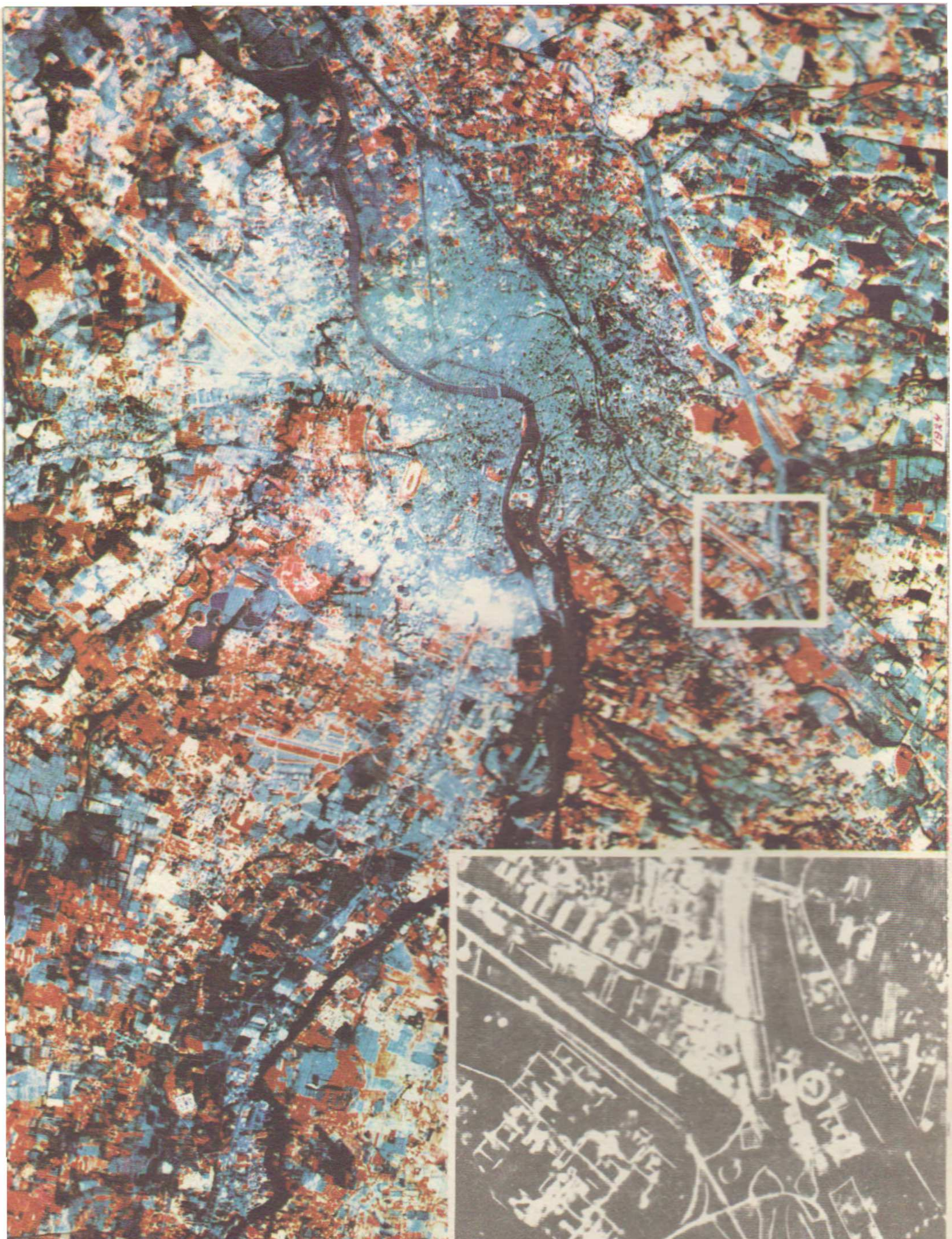
It has been wisely said that the State has now become too big for men – but too small for Mankind. Is the present proliferation of nations – over 150 at the moment! – a planetary cancer, or an evolution towards a healthier world, in which political structures will be built on a more human scale?

And to continue the analogy from evolution, let us remember something that happened on this planet once before. There was a time when it was dominated by monsters who tried to protect themselves by ever more cumbersome armour, until they were walking fortresses. They never noticed, as they blundered through forest and swamp, the little creatures that skipped out of their way: the first mammals – our ancestors.

Intelligence, not armour, was to inherit the Earth. May it do so once again.

The Spot 1 satellite was launched on February 22, 1986. Work is now continuing on Spot 2 due for launch in 1988. *Matra*





INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Queensland Spaceport for Australia

The Cape York Peninsula of Queensland, Australia has been proposed as the site of an International Spaceport for the 21st century. A report prepared after five months of feasibility study by representatives of Australian space technology identifies significant advantages for Cape York over most existing launch sites and concludes that present forecasts of traffic into space show that a potential segment of the commercial market could be captured.

The proposed site is at a latitude of about 12 degrees South and offers attractive meteorological conditions and access to the most important commercial orbits. The region also has the advantage of proximity to existing air and seaport facilities at the modern mining town of Weipa.

Two launch sectors have been proposed. The first is to the east and south-east over water and could service launches to equatorial orbits and to the US and Soviet Space Stations. The second is to the south-west over both water (the Gulf of Carpentaria) and land (Central Australia) and could service launches into polar orbits, including Sun-synchronous orbits.

The report is entitled "Cape York International Spaceport" and concludes Part I of a A$93,000 feasibility study. In receiving the report from Mr. Walter Stamm, President of the Institute of Engineers' National Committee on Space Engineering, the Premier and Treasurer of Queensland, Sir Joh Bjelke-Petersen, said that it was a promising start to an ambitious project which is attractive not only to private companies but of interest to other national governments.

Sir Joh said: "We will now be embarking on the next step by initiating the second phase of the study to determine the viability of the project."

He added that the State Cabinet had approved A$300,000 for further studies and the marketing of the project to interested consortia on an international basis.

Japan Begins Robot Arm Design

The National Space Development Agency of Japan (NASDA) is carrying out preliminary design work on the Japanese Experiment Module (JEM) for the international Space Station. The JEM's module remote manipulator system (JEMRMS) is one of JEM's subsystems and its main purpose is to handle the experimental equipment to be mounted on the JEM and the parts and equipment making up the JEM.

The JEMRMS consists of a master arm that handles large, heavy objects (up to seven tons), including the experimental logistic module (ELM), exposed facility (EF) and experiment payload, and a slave arm that handles considerably smaller and lighter objects (up to 700 kg), including experimental materials and samples, and orbital replacement units (ORU). The master arm is to be fitted at the base of the external section of the end cone of the pressurised module (PM). The JEMRMS is remotely controlled by a member of the crew inside the PM.

Commercial Experiments To Fly On Space Shuttle

3M and the National Aeronautics and Space Administration (NASA) have signed a 10-year agreement covering the company's commercial use of space.

The agreement will give 3M the opportunity to investigate relatively unexplored areas of microgravity research in Earth orbit, including materials processing in space experiments in the area of organic and polymer science, areas in which 3M specialises and has major interests.

The schedule of experiments includes two each per year in the Shuttle Orbiter middeck during the agreement's 10-year span, two each per year in the Shuttle Orbiter cargo bay during years one to three, and six each per year in the Shuttle Orbiter cargo bay during years four to nine.

Negotiations leading to the agreement began shortly after 3M scientists watched the first of three 3M space experiments go into orbit aboard Space Shuttle Discovery in November 1984. Their other two experiments were on Space Shuttle Atlantis in August 1985 and Discovery again in November 1985.

These first space-research efforts included two organic-crystal-growth experiments called Diffusive Mixing of Organic Solutions (DMOS-1 and DMOS-2) and one experiment to create thin films with ordered organic structures, which was called Physical Vapor Transport of Organic Solids (PVTOS-1).

The 3M experiments are considered secondary payloads because of their relatively small size and NASA has yet to announce a schedule for this type of payload.

World Watch From Space

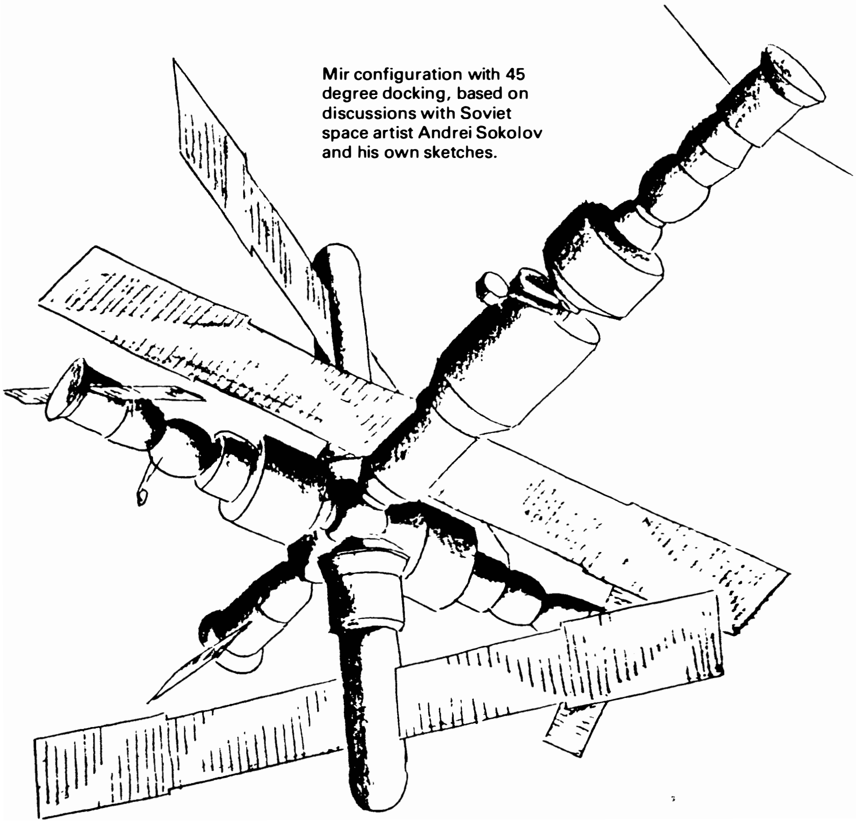
On the left is an image acquired by the Spot satellite while passing over Toulouse, France at an altitude of 822 km (511 miles) on March 5, 1986. The scene is in false colour at a scale of 1:100,000 with a 'zoom' inset in black and white at a scale of 1:25,000.

The colour image represents an area 30 x 20 km^2 with a ground resolution of approximately 20 m. Vegetation appears in a reddish colour, built-up areas in pale blue and water in deep blue. Trees, which are still bare, appear a dark colour. At the top left-hand corner Blagnac airport is clearly visible and in the middle of the picture La Cépière racecourse and the grass of the stadium are shown in red.

The black and white image has a resolution of 10 m and is focussed on the MATRA ESPACE plant where the MATRA emblem, consisting of an arrowhead within a circle, is clearly visible. On the left of this inset the runway of the small Montaudran airport is visible. *MATRA*

World Watch From Space continued on p.191 – *Ozone Depletion.*

Mir Dockin



Mir configuration with 45 degree docking, based on discussions with Soviet space artist Andrei Sokolov and his own sketches.

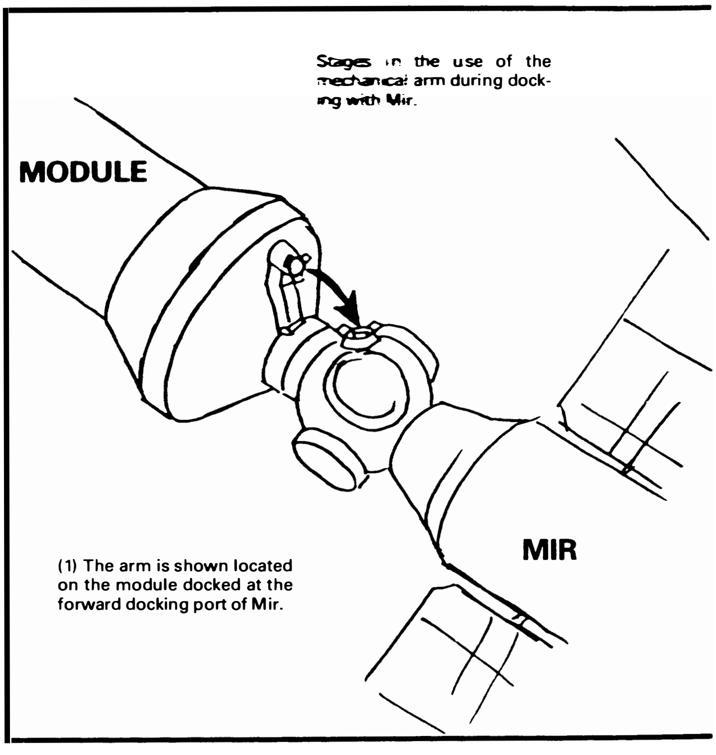
Mir's six docking ports are to play a key role in the planned build-up of the space station complex but many unknowns surround the intended docking programme and the station's final configuration.

In this special report for *Spaceflight*, *Lucien van den Abeelen* looks at some of the currently available information on Mir and the questions that it raises regarding forthcoming Mir dockings and operations.

Mechanical Arm

The mechanical arm to be used during docking procedures with the Soviet Mir station (the Ljappa system, as it is called) employs a short arm attached to the module's docking assembly [1]. Using only one joint, it is not as sophisticated as the Canadarm used on the Shuttle and could more appropriately be called an anchor.

A module will always dock at the forward docking port of Mir's ball-shaped multiple docking assembly, the one also used by Soyuz-TM (Sketch 1). The arm then swings round its attachment point and locks on to the docking socket located on the assembly (Sketch 2). For proper alignment of arm and socket, a three 'petal' structure is used, similar in design to the androgenous docking system developed under the



Stages in the use of the mechanical arm during docking with Mir.

(1) The arm is shown located on the module docked at the forward docking port of Mir.

Astrophyics Module Extends Mir

The Soviet astrophysics module launched by a Proton rocket from the Tyuratam space centre on March 31 docked with the rear port of the Mir Space Station at 04.36 Moscow Time on April 9.

This was the second attempt to dock automatically the 20.6 ton spacecraft, the first having been aborted on April 5 due to technical problems. Initial reports on April 9 indicated there were still difficulties, however, and that the two vehicles were not fully linked.

After completion of docking operations the service pod and space tug were due to be jettisoned, leaving the 11 ton module, which is 5.8 m long with a maximum diameter of 4.15 m, attached to Mir.

The module, called Kvant (quantum), is in three sections – the laboratory bay, transfer compartment and the scientific payload bay. The first of these forms air tight quarters of some 40 m^3 capacity. The scientific payload bay is not hermetically sealed.

The laboratory bay accommodates the main research equipment which is mounted in an "instrument section" and separated from the actual dwelling compartment by "decorative panels". Also housed here are a number of control systems.

The bay has two view ports, one 43 cm in diameter for an "optical device" and the other 22.8 cm for a visual star tracker. There are two further 8 cm port holes and an airlock chamber for servicing the ultraviolet telescope in the transport compartment.

Equipment includes: Pulsar X1 hard X-ray spectrometer, Fosvich high energy scintilation spectrometer, Siren 2 proportional gas scintilation spectrometer, Glasar telescope and Svetlana automated electrophoresis plant.

gs and Operations

Apollo-Soyuz Test Project. Once the arm is secured, the docking probe of the module is retracted and the entire module is raised slightly (Sketch 3). It is then free to swing round the socket on Mir and can re-dock on one of the side-ports (Sketch 4).

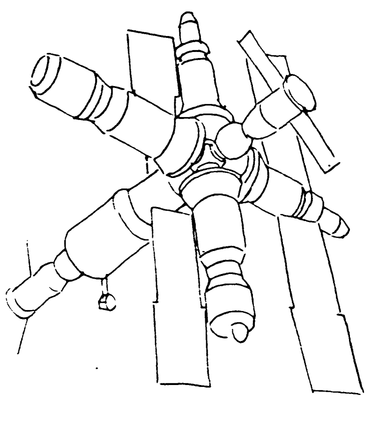
The three-petal structure is not visible on Mir in pictures of mock-ups or in pre-launch or in-orbit pictures. It is possible a space-walk by Laveikin and Romanenko is required before a module can dock.

Some questions remain about the final configuration and operation of Mir. In Soviet drawings [2], four modules are shown docked to the side-ports of Mir. They are large modules, without secondary docking ports of their own. When four of these modules are docked, and there is a Progress at the aft port, one port remains free for a Soyuz-TM craft. How, then, do the Soviets intend to get six cosmonauts on board as this has been stated as the capacity of Mir?

A second question is concerned with orbit decay. Is the current Progress freighter capable of boosting a 120 ton complex into a higher orbit, as done before with Salyut and Mir? Is a more powerful Progress version under development?

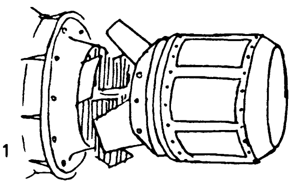
In the Soviet drawing, there are no Cosmos 1669-type modules visible. What will its role be in the Mir programme if any? Or is it the successor to Progress?

The accuracy of the Soviet drawing is, of course, questionable. For instance, the diagrams of the Mir station projected on the giant screens in the Kaliningrad control center show mistakes. One of these diagrams is visible in a picture taken during the Mir-part of the Soyuz-T 15 mission [3]. This shows the solar panels of Mir and Soyuz being in the same plane. From TV footage of the Soyuz-T 15/Mir docking it is clear that Soyuz is inclined 45 degrees to the horizontal (through Mir's solar panels).



Mir based on Soviet drawing showing solar panels of Mir and Soyuz in same plane.

In a meeting I had with Soviet space artist Andrei Sokolov last summer, he told me all modules would dock 45 degrees inclined. Again, this is not visible in the Soviet drawing. Sokolov also said two kinds of modules were available for Mir; a long one and a short one, which he sketched for me. The long one is visible in the Soviet drawing. It has a strangely narrow end part. Perhaps a re-configured cargo descent module? The short module may be the one shown in photographs of Mir training mock-ups, known as the rear-module. Several of these docked to Mir would provide secondary docking ports, thus enabling more than three cosmonauts to go aboard.



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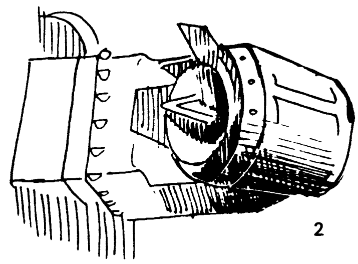
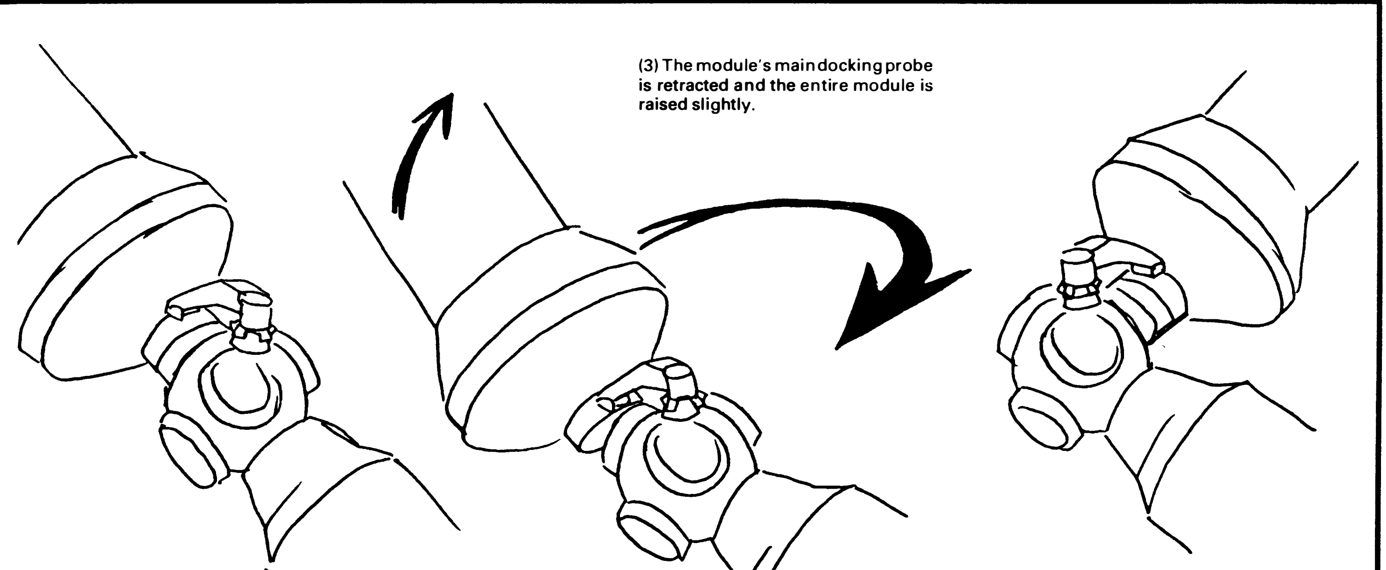


2

The Ljappa system: (1) The end of the mechanical arm about to engage the three-petal socket on Mir; (2) View of the underside of the end of the mechanical arm [1].

References

1 Station Orbitale Sovietique MIR Dossier de Presse, Cosmos Club de France
2 Aarde & Kosmos (Dutch magazine) 1987 No 1, p 126
3 Flight International, 10 May 1986, p 26



(2) The arm locks on to the socket located on Mir's ball-shaped multiple-docking assembly;

(3) The module's main docking probe is retracted and the entire module is raised slightly.

(4) The module swings round the socket on Mir through 90 degrees and re-docks at a side-port.

SATELLITE DIGEST – 202

Robert D. Christy
Continued from the April, 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1810, 1986-102A, 17262.
Launched: 1100, 26 December 1986 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 248 x 265 km, 89.66 min, 64.76 deg, manoeuvrable.

MOLNIYA-1 (70), 1986-103A, 17264.
Launched: 1526, 26 December 1986 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system within the USSR.
Orbit: Initially 447 x 39079 km, 701.04 min, 62.78 deg then raised to 475 x 39876 km, 717.70 min, 62.82 deg, to ensure daily repeats of the ground track.

METEOR 2 (15), 1987-1A, 17290.
Launched: 0122, 5 Jan 1987 from Plesetsk by A-2 or F-2.
Spacecraft data: A cylinder with a pair of Sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at one end. The length is probably about 5 m, diameter 1.5 m and mass around 2000 kg. Stabilisation is by the use of momentum wheels.
Mission: Meteorological and remote sensing satellite.
Orbit: 942 x 961 km, 104.14 min, 82.47 deg.

COSMOS 1811, 1987-2A, 17292.
Launched: 1238, 9 January 1987 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period. It re-entered on 13 February 1987 after 35 days.
Orbit: 171 x 347 km, 89.69 min, 64.87 deg, manoeuvrable.

COSMOS 1812, 1987-3A, 17295.
Launched: 0906, 14 January 1987 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of Sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 634 x 665 km, 97.78 min, 82.55 deg.

COSMOS 1813, 1987-4A, 17297
Launched: 1120, 15 January 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the, forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, retro-fire failed, so the re-entry module was deliberately destroyed by explosion on 29 January 1987.
Orbit: 356 x 415 km, 92.32 min, 72.82 deg.

PROGRESS 27, 1987-5A, 17299.
Launched: 0606*, 16 January 1987 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Unmanned supplies carrier for Mir, which was also used to set up rendezvous conditions for Soyuz-TM 2 and to raise the station's orbit. It docked with Mir's rear port at 0727 on 18 January. It undocked at 1129 on 23 February, then re-entered after retro-fire at 1517 on 25 February.
Orbit: Initially 185 x 260 km, 88.90 min, 51.63 deg, then raised to 312 x 343 km, 91.03 min, 51.62 deg for docking with Mir. On 18 January, a firing of the Progress engine raised Mir's orbit to 328 x 363 km, 91.39 min, 51.62 deg.

COSMOS 1814, 1987-6A, 17303.
Launched: 0913, 21 January 1987 from Plesetsk by C-1.
Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 771 x 810 km, 100.72 min, 74.07 deg.

COSMOS 1815, 1987-7A, 17326.
Launched: 0702, 22 January from Plesetsk by C-1.
Spacecraft data: Possibly similar to the navigation satellites, in which case it has a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Electronic intelligence gathering.
Orbit: 374 x 580 km, 94.09 min, 50.67 deg.

MOLNIYA-3 (31), 1987-8A, 17328.
Launched: 1601, 22 January 1987 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite pro-

NASA Launches Indonesian Satellite

The Indonesian satellite Palapa-B2P is now on station south of Borneo in geosynchronous orbit following launch on March 20 from Cape Canaveral by NASA using a Delta rocket.

Palapa-B2P is the second spacecraft in a two-satellite system, replacing Palapa-B2 which was successfully deployed from the orbiter Challenger on mission 41B in February 1984, but failed to achieve geosynchronous orbit due to a payload assist module (PAM) malfunction. Palapa-B1 has been operating since it was delivered to orbit from mission STS-7 in June 1983.

Palapa-B2P is designed to provide 24 additional channels of C-band service to the communications network that provides service to the more than 13,000 islands of Indonesia and to the Association of South East Asian Nations (ASEAN) countries and Papua New Guinea. ASEAN includes the Philippines, Thailand, Malaysia and Singapore. The channels, or transponders, will improve quality and efficiency to voice, video, telephone, telegraph and high-speed data transmissions.

Palapa-B2P was originally scheduled for launch by a McDonnell Douglas Payload Assist Module (PAM) from the Space Shuttle last year. When the Shuttle launch was cancelled, the satellite was assigned to fly on a Delta rocket. Since PAMs can be used on either the Shuttle or a Delta, the same PAM that was scheduled to launch Palapa from the Shuttle was used.

The Delta vehicle used to put Palapa into orbit was one of the last rockets built for NASA before the production line was halted in early 1984. Delta production started again last September when NASA ordered three new rockets. In January, NASA announced it was ordering a fourth Delta, which will launch the Cosmic Background Explorer in 1989.

Also in January, the US Air Force selected McDonnell Douglas to build and launch seven upgraded versions of the rocket for its Medium Launch Vehicle programme.

The final Delta mission scheduled for this year is a Department of Defense payload that will fly in November. Over the last nine years and 46 launches, Delta has achieved a 98 per cent success rate.

Indian Satellite Launch Loss

An Indian science satellite was lost at the end of March when its augmented satellite launch vehicle (ASLV) failed.

The ASLV, developed by the Indian Space Research Organisation (ISRO), was the first of four and carried a stretched Rohiri series (SRS) scientific satellite.

The launch, from Sriharikota, should have placed the 330 lb satellite into low Earth orbit. The ASLV, a four stage solid propellant booster with two additional strap-on boosters, suffered a malfunction in its second stage.

Lightning Theory of Failed Launch

An Atlas Centaur launch vehicle carrying a Fleet Satellite Communications (FltSatCom) military payload was destroyed by range safety officers 71 seconds after lift-off at Cape Canaveral on March 26 in a heavy rainstorm with lightning nearby. The destruct command was sent when the rocket began to veer off course and break up.

Although a military payload, launch operations were in the hands of NASA which has set up an enquiry team to investigate the cause of the failure. Engine performance was satisfactory according to telemetary data and attention now centres on weather conditions particularly on the presence of nearby lightning strikes.

One further and final FltSatCom satellite, which was scheduled for launch on June 11, will now wait until the cause of the failure has been identified.

Delta Satellite Reservations

McDonnell Douglas has received nine down payments to reserve future launch dates for commercial satellites on its Delta II Medium Launch Vehicle.

The nine launch reservations are from eight organisations: Communications Satellite Corp. in Washington made two reservations and the following each made one: Contel ASC, formerly American Satellite Co., Rockville, Maryland; Hughes Communications Satellite Services Inc., Los Angeles; the Government of India; and Pacific Satellite Inc., Washington. Three organisations declined to be identified.

Delta II launches for commercial customers will begin in late 1988 or early 1989. The company will have the capacity to launch up to 12 commercial satellites per year in the early 1990s.

In January, the Air Force awarded McDonnell Douglas a contract to build and launch seven Delta II rockets, with options for 13 more. At the same time, McDonnell Douglas has been actively marketing the Delta II to commercial customers.

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viding telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: 435 x 40809 km, 735.89 min, 62.81 deg, then lowered to 461 x 39893 km, 717.76 min, 62.85 deg to ensure daily repeats of the ground track.

COSMOS 1816, 1987-9A, 17359.
Launched: 0615, 29 January 1987 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 965 x 1011 km, 104.93 min, 82.93 deg.

COSMOS 1817, 1987-10C, 17368.
Launched: 0919, 30 January 1987 from Tyuratam by D-1-e.
Spacecraft data: A stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Intended geosynchronous communications satellite injected into low Earth orbit after its final rocket stage failed to fire.
Orbit: 212 x 260 km, 89.17 min, 51.59 deg.

UPDATES:

1985-34B, NUSAT decayed on 15 December 1986 after 595 days.
1985-104B, GLOMR decayed on 26 December 1986 after 422 days.
1985-118A-C, COSMOS 1710-1712 – the launch vehicle was D-1-e.
1986-25A, COSMOS 1737 re-entered on 3 December 1986 following retro-fire after 253 days.
1986-71A-C, COSMOS 1778-1780 – the launch vehicle was D-1-e.
1986-87A, COSMOS 1792 re-entered on 5 January 1987 after 53 days.
1986-99A, COSMOS 1807 re-entered on 23 January 1987 after 38 days.
1986-60A, COSMOS 1770 re-entered on 2 February 1987 after 180 days.

INTERNATIONAL SPACE REPORT

UK Joins Hermes Preparatory Programme

The UK has joined other members of the European Space Agency (ESA) in the preparatory programme for ESA's Hermes manned spaceplane.

The decision was announced in Paris on March 19 by Roy Gibson, Director-General of the British National Space Centre, at a meeting of the ESA Council Group during preparations for the next ESA Ministerial Council this summer.

Mr. Gibson said: "Britain's £2m contribution means that it will acquire the necessary visibility in the Hermes programme and should enable us to gain extremely valuable experience in advanced new technologies employed on the project."

He emphasised that Britain's decision was at present limited to the current preparatory programme and did not in any way constitute a commitment to any subsequent development programme, which would have to be decided upon following the next ESA Ministerial Council.

Several British companies and universities are expected to benefit from the preparatory programme including British Aerospace at Warton and Stevenage; GEC Avionics of Rochester; Smiths Industries at Cheltenham; and the Universities of London, Swansea, Oxford and Southampton, as well as the Cranfield Institute of Technology.

Sweden Conducts Microgravity Research

The first launch of the Swedish sounding rocket programme MASER took place at Esrange, the Swedish Space Corporation range in Kiruna, Northern Sweden on March 19.

A payload including a 60 per cent contribution from the European Space Agency's Microgravity Programme was flown in microgravity conditions for seven minutes 15 seconds. Experiments from ESA member states, including Germany, the Netherlands, Sweden and Italy were carried, covering basic research in areas such as immiscible alloys, metallurgy and the heat transfer and surface tension properties of liquids. Although focussed primarily at basic scientific research, the results of this type of experiment may contribute significantly to the understanding of those physical phenomena responsible for determining the properties of new materials with potential for future applications.

Sounding rocket programmes of this type, including the German Texus programme (in which ESA also participates to a level of about 50 per cent), have successfully provided over the last few years flexible and consistent flight opportunities for microgravity research.

Independent from large space systems, such as Shuttle/Spacelab programme, they offer in the era leading up to the utilisation of Space Station/Columbus a regular means of carrying out experiments in a rapid, flexible and repeatable manner, thus ensuring continuous access to the microgravity environment for a growing scientific community.

Microgravity research is carried out in the free floating conditions obtained in orbital and sub-orbital space flight where near weightlessness of about one ten thousandth of the force of gravity at the Earth's surface can be obtained.

Increased Safety Measures

A new reference baseline for Hermes and Ariane 5 is being considered following a reappraisal of Hermes safety requirements and a detailed analysis of the initial Hermes configuration.

As a design goal, the total mass of Hermes has been assumed to be 21 tons in a low circular Earth orbit of 500 km and an inclination of 28.5 degrees. The total mass of Hermes includes a payload of three tons plus mission fuel of 1.5 tons. This would result in a corresponding adaptation of Ariane 5 configuration from two solid boosters of 190 tons and a liquid core stage of 140 tons to an updated version with two solid boosters of 230 tons and a liquid core stage with 155 tons of propellant.

According to the revised concept, the Hermes spaceplane would be designed with an ejectable crew cabin as a more advanced safety system. Hermes would have a crew of three, a pressurised cargo bay and an adapted fuselage with respect to these changes.

Hermes is foreseen to service the European contribution to the future manned space station and, in particular, the Man Tended Free Flyer (MTFF). The MTFF constitutes an element of the European Columbus in-orbit infrastructure programme. It will be a periodically manned laboratory for microgravity experiments.

A task force has been established to review the overall coherence between Hermes, Ariane 5 and MTFF. The members consisting of representatives of the European Space Agency (ESA), national space agencies of ESA member countries and industry, are due to present their findings this month (May).

Initiated by the Centre National d'Etudes Spatiales (CNES) in 1976, the Hermes spaceplane became an ESA programme in December 1986. Under ESA authority, CNES manages the preparatory programme.

Pioneer 9

NASA's Pioneer 9 spacecraft, which has orbited the Sun for almost two decades, was declared officially out of operation in March after a final attempt to contact it was unsuccessful.

The last signal from Pioneer 9 was received on May 18, 1983. Since then, controllers have made a number of attempts to reach the spacecraft when equipment availability and positions of the Earth, Sun and spacecraft permitted, but they were unable to pick up a signal.

On March 3, 1987 in a last-ditch attempt to revive the spacecraft, engineers at NASA's Ames Research Center in Mountain View, California used a wide variety of combinations of transmitter, antennas and receivers, including an especially sensitive receiver developed for NASA's Search for Extraterrestrial Intelligence prog-

INTERNATIONAL SPACE REPORT

Columbus Contracts for Logica

Logica has been awarded contracts worth over £500,000 for Phase B2 – the detailed definition phase – of the European Space Agency's Columbus programme, by prime contractor MBB-ERNO.

Logica's main task in this phase is to manage the definition of the system software which will comprise:

- Onboard system and mission management software.
- Ground-based mission preparation software.
- Software technology support.

Software companies from several European countries are brought together in the Logica-led consortium, which includes teams from Denmark and W. Germany.

In addition, Logica continues in Phase B2 to work on projects begun in earlier phases. These include contracts with:

- Aeritalia of Italy for human factors, man-machine interface and software engineering consultancy for the manned elements of Columbus.
- Matra of France on system and software aspects of the data management system, which is used in all elements of Columbus.
- British Aerospace on payload operations aspects of the polar orbiting platform.

UK/Soviet Agreement on Space

A ten-year co-operation agreement on the study, exploration and use of outer space was signed in Moscow at the end of March by Foreign and Commonwealth Secretary, Sir Geoffrey Howe, and Soviet Foreign Minister, Eduard Shevardnadze.

The agreement followed a protocol signed by Roy Gibson, Director General of the British National Space Centre (BNSC) and Academician R. Sagdeyev of the Soviet Institute of Space Research in Moscow last October.

The BNSC will administer the agreement on behalf of the UK space community. It consolidates and formalises existing collaboration between UK Universities such as Birmingham and London and the Soviet Space Research Institute.

The agreement provides for co-operation in classical space sciences, such as x-ray astronomy, high energy astrophysics, solar and terrestrial physics and life and material sciences.

As a result, there will be co-operation through exchanges of experts and experience, and sharing in joint research, such as the planned Soviet mission to Phobos in 1988.

Three British interdisciplinary scientists have been chosen to collaborate on the Phobos Mission: Professor David Southwood of Imperial College, London; Professor Greville Turner of the University of Sheffield and Dr. John Guest of the University of London Observatory. They will attend science workshops in the Soviet Union prior to launch and participate in analysis of data resulting from the mission.

Space Station Communication Terminal

Marconi Space Systems of Portsmouth, England, has been awarded a £300,000 contract by the European Space Agency (ESA) to commence work on the development, assembly and test of a satellite communication terminal.

Such terminals will be required to handle the large volumes of data generated by commercial and scientific payloads to be carried by the various elements of the European manned space station complex, Columbus.

Technological advances are expected to be made in electronic filters and in modulation and demodulation equipment to cater for 500 megabit per second data transmission. A simulator representing the data flow over a relay satellite link to ground, will allow system evaluation to be made. A steered multi-frequency antenna is also to be modelled.

The terminal will be compatible with the United States Tracking and Data Relay Satellite system already in operation and eventually with the proposed European Data Relay satellite.

– "Dead" After 18 Years

ramme. Eighty command sequences, totalling 270 commands, were transmitted to the spacecraft. However, no signal was detected.

The final attempt to reach Pioneer 9 came 18 years after it was launched, on November 8, 1968.

Pioneer 9, which had a design-life of six months, was one of a fleet of four NASA spacecraft which have orbited the Sun since the late 1960's. Pioneer 9 and its sister spacecraft, Pioneers 6, 7 and 8, which continue to function, were among the earliest interplanetary probes.

The solar-orbiting Pioneers made the first detailed, comprehensive measurements of the solar wind, solar magnetic field, and cosmic rays. Since the Sun is thought to be typical of many stars in the universe, the Pioneer data provided insights into stellar processes. Until 1972, the Pioneers also supplied practical data on solar storms which affect communications on Earth. The four Pioneers have rarely been tracked in recent years, since newer missions have required time on NASA's Deep Space Network antennas.

Pioneer 9 has circled the Sun 22 times, covering 11 billion miles, its 297-day orbit ranging from within 78 million miles to 90 million miles from the Sun (just inside Earth's orbit). The 148-pound spacecraft sent 4.25 billion bits of data back to Earth during its operational lifetime.

Engineers have speculated that Pioneer 9's demise could have been due to an electrical short-circuit caused by a worn-out part. A remote possibility is that the spacecraft was hit by a meteor.

As they have aged, all four solar-orbiting Pioneers, which are solar-powered, have turned themselves off due to circuit overload when at their farthest from the Sun. However, until now, mission controllers had always been able to command the spacecraft back on by radio signal. Pioneer 9 will continue to orbit the Sun indefinitely, but in all likelihood will never again transmit data to Earth.

Pioneer 9's accomplishments include determining the structure and flow of the solar wind, the million-mile-an-hour stream of ionized gases which spirals out from the Sun. Pioneer 9 and the other solar-orbiting Pioneers also measured the twisted magnetic fields threading the solar wind and the high-energy particle streams which follow the course of the magnetic field out from the Sun.

Before the Pioneer findings, the solar wind was thought to be a gentle, steady flow.

INTERNATIONAL SPACE REPORT

International Space Year

The International Council for Scientific Unions (ICSU) has agreed that 1992 should be designated International Space Year (ISY) when, through enhanced global co-operation, the achievements and benefits of current and prospective space programmes will receive greater prominence.

It is hoped to highlight the many contributions of the space sciences to human progress and to convey, through special events during the year, how space exploration can advance civilisation. The types of events envisaged are ones to promote understanding and collaboration between scientists, educators, policy-makers and the general public. A proposed central theme for ISY is 'Understanding and Utilising Space for Humanity'.

1992 has been chosen as it will be the 500th anniversary of the landfall of Columbus in the New World and the 35th anniversary of the International Geophysical Year and thus of the beginning of the space era. By that date it is hoped to have set in place platforms for global observations of the Earth from space and from networks of Earth-based stations. The ISY could also highlight other existing and planned international programmes in areas like space astronomy, solar-terrestrial physics, and exploration of major and minor planets.

The ICSU believes that the exploration and discovery aspects of the ISY will stimulate the imagination of the public of all ages, providing an important occasion for the diffusion of knowledge and for a wide range of educational activities. The ISY could also prompt consideration of creative, visionary proposals that will increase international cooperation in space, including the development of a consensus about future targets for joint missions and a new world commitment to the peaceful exploration and utilisation of space for the benefit of all.

Satellite Supercomputer

Smith Associates (SA) of Guildford, England has been awarded a contract by ESA to develop a transputer-based fault-tolerant supercomputer small enough to be carried aboard satellites.

SA claim the transputer is particularly attractive for space applications because transputer arrays require a minimum of external support circuitry, provide very high performance and can be connected in fault-tolerant configurations. Benefits include real-time picture compression, greater autonomy for distant satellites and on-board pre-processing in communictions satellites.

Paris Air Show

The 37th International Air and Space Show will be held at the Le Bourget Airport outside Paris from June 12 to 21, 1987. The inauguration ceremonies will be held on the morning of 11th and an initial preview will be held for members of the press in the afternoon. The show will be open to the public on 12, 13 and 14 and on the final weekend (20 and 21); the 15th to 19th are reserved for professionals and journalists.

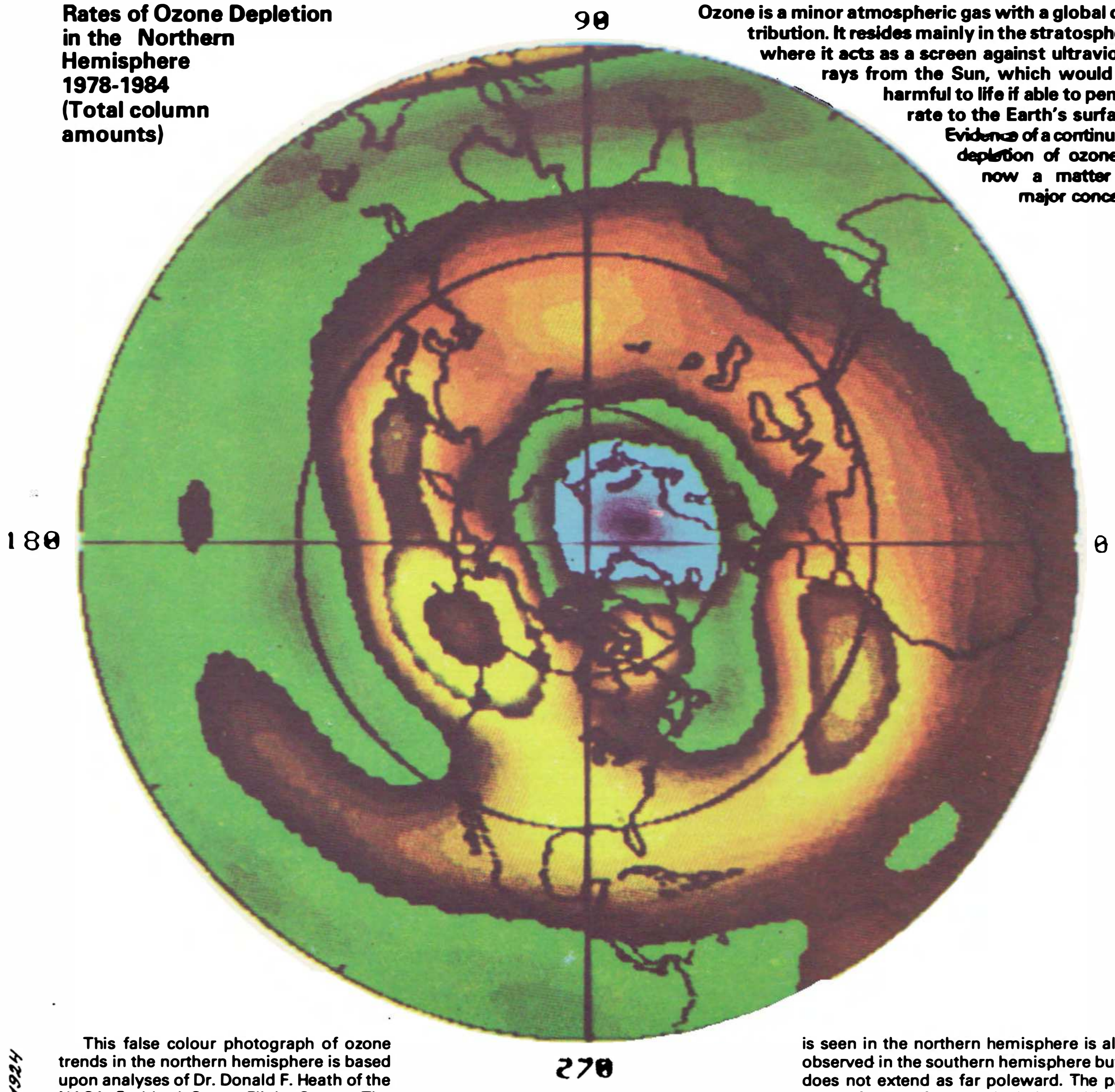
A full-scale model of Hermes, the future European spaceplane is to be exhibited by the French national space agency, CNES.

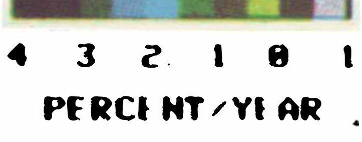
The British National Space Centre will have a large presence with a 50 sq metre stand featuring a continuous video presentation on the centre, its national and European Space programmes and the capabilities of universities, manufacturers and the service sector. Exhibits will range over satellite communications, earth observation, the International Space Station and Columbus programmes, astronomy and solar science, and Hotol.

Ozone Depletion

Rates of Ozone Depletion in the Northern Hemisphere 1978-1984 (Total column amounts)

Ozone is a minor atmospheric gas with a global distribution. It resides mainly in the stratosphere where it acts as a screen against ultraviolet rays from the Sun, which would be harmful to life if able to penetrate to the Earth's surface. Evidence of a continuing depletion of ozone is now a matter of major concern.





This false colour photograph of ozone trends in the northern hemisphere is based upon analyses of Dr. Donald F. Heath of the NASA Goddard Space Flight Center. The ozone data were computed from observations with the Solar Backscatter Ultraviolet (SBUV) instrument which was launched aboard the Nimbus 7 satellite in October 1978 into a circular sun-synchronous polar orbit (110° inclination) at an altitude of about 950 km. Dr. Heath has also developed and prepared Backscatter Ultraviolet instruments for measuring ozone total column amounts and the corresponding profiles from the Nimbus 4, Atmospheric Explorer 5 and NOAA 9 satellites which were launched in April 1970, November 1975 and December 1984 respectively.

In the northern hemisphere tropics ozone is decreasing at a rate of about 1.0 per cent per year (green). At mid-latitudes the rate of ozone decrease is slightly less, 0.5 – 1.0 per cent per year (orange). The rate of ozone decrease around the 30° latitude circle varies from 1 per cent per year at a longitude of 180° to 0.6 per cent per year at 270° and to 0.4 per cent per year at 360°. At 60° latitude there is a region south of Alaska, longitude 210°, where ozone is increasing (red) which reaches a maximum value of 0.2 per cent per year. The largest rates of decreasing ozone in the northern hemisphere are observed in the sector (blue) poleward of 60° and between longitudes of 330°-120° with the region of largest rate of decrease (1.2 per cent per year) in the vicinity Spitzbergen.

Results are also available for the southern hemisphere. The tropical rate of ozone decrease of about 1 per cent per year which is seen in the northern hemisphere is also observed in the southern hemisphere but it does not extend as far poleward. The patterns of rates of ozone depletion exhibit a much greater zonal symmetry in the southern hemisphere than in the northern hemisphere. The 30° latitude circle is characterised by a zone of minimum rate of ozone of about 0.4 per cent per year. Poleward of 30° latitude the rate of ozone depletion accelerates rapidly reaching a maximum rate of 2.6 per cent per year which is offset from the pole at a longitude of 30°.

Intercomparisons of satellite measurements of total column ozone amounts with those obtained with ground-based Dobson instruments as the satellite passes over the station indicate that the ozone values from the satellite are decreasing at an average rate of about 0.3 per cent per year relative to the Dobson network. In order to reference the ozone trends reported for the northern and southern hemispheres to the Dobson network the rates of ozone decrease should be reduced by 0.3 per cent per year or shifted by about one colour bar.

Space Instruments Study Ozone Phenomena

by John Bird

Life on Earth is dependent on the ozone layer of the atmosphere to act as a shield from the deadly ultraviolet rays from the Sun. Over the last two decades, and since 1980 in particular, there has been a mysterious decrease in ozone levels in the atmosphere in the polar regions of the Earth. Because of this potential danger efforts to understand the "ozone hole" phenomenon have recently intensified.

Nimbus-7 Satellite

Nimbus-7 is a weather satellite carring several instruments that monitor ozone and other related chemicals such as nitrogen dioxide. It was launched on October 24, 1978.

Images of ozone distribution over the Earth have been provided by an instrument called the Total Ozone Mapping Spectrometer, TOMS, which is part of the Nimbus-7 weather satellite.

Another instrument on Nimbus-7 which monitors ozone is called the SBUV (Solar Backscattered Ultraviolet). It is an optical instrument that looks at 12 wavelengths from 312 to 340 nm.

The Stratospheric Aerosol Measurement II (SAM II) is another Nimbus-7 instrument that monitors the aerosol layer in the Earth's stratosphere. Aerosols are microscopic particles (either liquid or solid), and it has been suggested that they are related to ozone depletion.

Space instruments that have provided information for investigating the ozone depletion problem include:

- Stratospheric Aerosol and Gas Experiment (SAGE), launched February 1979.
- SAGE II, launched October 1984.
- Stratospheric Aerosol Measurement II (SAM II), launched October 1978 on Nimbus-7.

These three instruments were used to provide simultaneous measurements of ozone, nitrogen dioxide, and aerosols, which interact in the atmosphere. Nitrogen dioxide plays an important role in the interaction between dynamical and chemical effects.

Location of the Ozone Hole

Most ozone depletion studies have focused their attention on the ozone "hole" over Antarctica. This hole is a region where the least amount of ozone is found. Another ozone hole has been detected over the Arctic. Although the effect of the second hole is not as pronounced it has been of concern because it is close to major population centres.

The total ozone over Antarctica varies during the year, with a minimum in October. It is this minimum amount of ozone, which has been declining markedly since 1979, that has been the cause of concern.

In 1979 the total amount of ozone measured during the October minimum in Antarctica was 260 Dobson units. By 1985 it was down to 150 DU, which corresponds to a 40 per cent depletion. During the two decades prior to this decline, (i.e. from 1960 to 1979), a relatively slight decline was observed. The minimum values observed in October recover to normal values by the end of November when sunlight in the southern hemisphere chemically creates ozone. The ozone minimum in the northern hemisphere occurs at the same time as the minimum in the Antarctic. The changes may therefore be related to fluctuations in the energy output of the Sun.

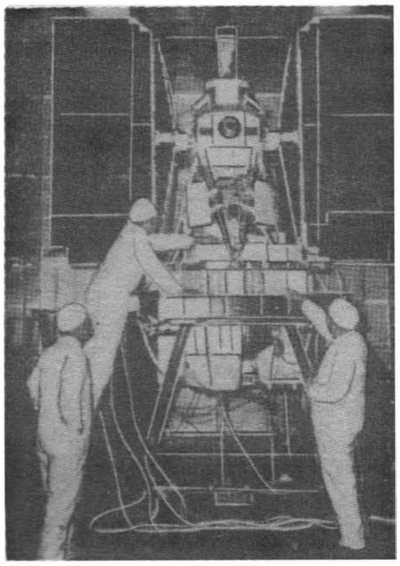
What is ozone?

Ozone is a from of oxygen, having three oxygen atoms and labelled 0_3, whereas the oxygen we regularly breath contains two oxygen atoms and is labelled 0_2. Ozone is sometimes created by high voltages, so it is possible to smell ozone near high voltage electrical wires.

Ozone in the atmosphere is only a minor trace constituent, even at altitudes where it has maximum concentration. Its maximum concentration occurs in a layer at 20 to 30 km altitude where there are 4×10^{12} molecules per cm^3, whereas oxygen at that height has 2×10^{17} molecules per cm^3. In other words for every ozone molecule at 25 km altitude, there are 100,000 oxygen molecules.

Ozone Depletion

Two basic mechanisms have been suggested as a possible cause of the ozone depletion: chemical reactions, and dynamic effects in the atmosphere where the ozone is redistributed by winds. If chemical reactions are responsible, the depletion could be due to chlorofluorocarbons (CFC's), which catalytically react with ozone to destroy it, while creating ClO and molecular oxygen.



Nimbus 7.

It has therefore been suggested that mankind's activities may threaten the ozone layer. For example, chlorofluorocarbons created by industry float up to the stratosphere where they produce chlorine that consumes the ozone. It was once thought that supersonic aircraft produced chemicals that would destroy ozone. Apparently this has not occurred.

Ozone depletion could be due to mankind's activities or it could be a natural phenomena. If it is a combination of both mechanisms, it may be difficult to identify the main cause. In any case, it is obvious that we must study this problem.

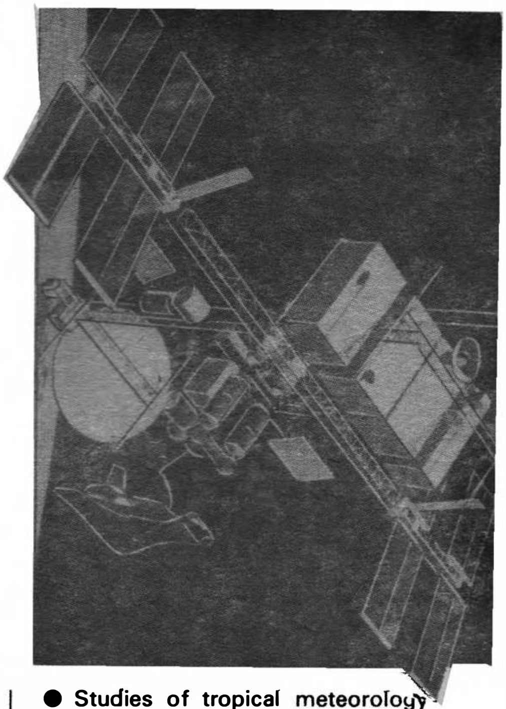
Satellite data are being used in conjunction with data taken from ground-based instruments, balloon-borne instruments and computer models. By combining these techniques it will hopefully be possible to determine the cause of the ozone depletion and remove much of the mystery that now surrounds the problem.

US Explores Ozone Hole

Three American agencies, the National Science Foundation, National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) are supporting high priority research into ozone depletion over Antarctica. The depletion is a springtime phenomenon, peaking in October, and during such months observations are of the greatest importance.

American ground-based activity is centred on the research station at McMurdo Sound and involves the release of huge high-altitude balloons carrying instruments for the measurement of ozone and other trace atmospheric gases. Results will be compared with computer models in an attempt to understand the cause of the year-by-year increase in the springtime depletions. According to the British Antarctic Survey, the amount of ozone over Halley Bay, in the eastern part of the Weddell Sea, has decreased every spring since 1975.

Space Station
OPPORTUNITY FOR
UK in Earth Sensing



by John Plevin and David Lynn*

Although the launch of the Space Station is still some 10 years away a start is needed now to prepare for the operational use of remotely sensed data. In the following article a UK sensor development programme that compliments instruments provided through ESA is suggested together with an adequately funded UK Polar Platform Preparatory Programme to develop applications and to prepare the user community. Operational success of the Polar Platform will depend on the existence of effective institutional arrangements to cover the orbital operations and ground segment management. The authors propose that the UK takes the lead in studying the available options and recommending preferred solutions to ESA.

Spaceborne Remote Sensing

The long term potential of spaceborne remote sensing for users in science, government and commerce will be based on the ability of space platforms to meet a number of essential requirements These are:

- Synoptic and repetitive coverage.
- Accurate and timely information.
- Continuity of data supply.
- Cost effective access to data.

To date, apart from meteorological applications, satellite remote sensing has not succeeded in providing all of these essential characteristics in a consistent way. An immediate result of this shortfall in capability is that many users remain uncommitted to the operational use of space techniques. Clearly, this needs to change if the full potential of space is to be realised. It follows therefore, that the success of the Space Station programme for Earth observation missions will depend on the ability of the proposed Polar Platforms to provide operational data for the science and applications community.

The Polar Platform concept has the potential to provide the characteristics listed above. The capacity to succeed is dependent on setting ground rules at the start of the design process and ensuring that they are maintained throughout the programme. If designers fail in their task the operational role of the Polar Platform for remote sensing could be severely set back and it will be difficult to persuade funding authorities to continue to provide the high levels of cash needed to continue platform operations. However, it is believed that current limitations in the quality and continuity of space data can be overcome and the foundation laid for the successful operational use of the Polar Platform for Earth observation missions.

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The approach which should be adopted is:

1. Identify the key applications needed to attract a large and enthusiastic user community to the programme.
2. Define the measurement requirements associated with these applications in terms of: sensors and payloads; constraints on the platform and orbit; data management requirements.
3. Identify gaps in current capability to apply remotely sensed data and to indicate the research and development needed to fill them.
4. Discuss the organisational issues that need to be addressed if the Polar Platform is to be operated and managed successfully.

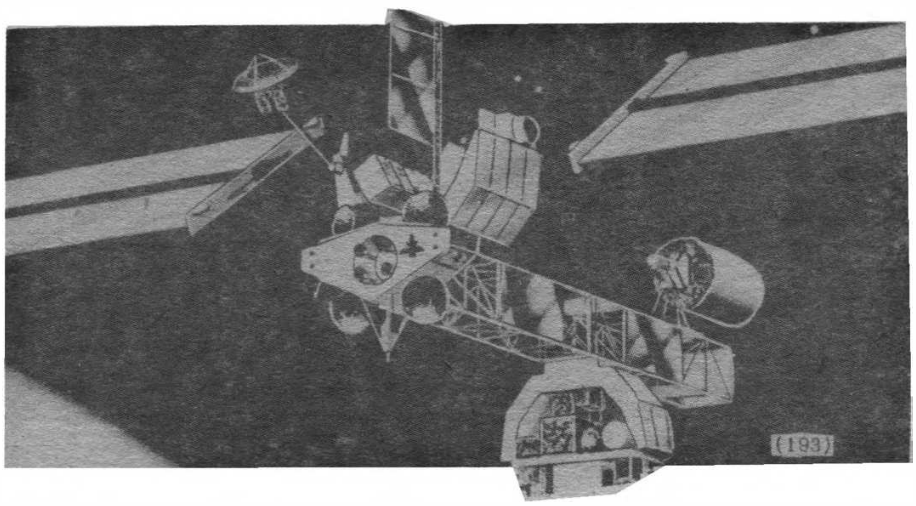
Whilst emphasis is given to the opportunities provided by the Polar Platform it should be remembered that the 28.5 degree elements of the Space Station also have a useful, albeit limited, role for the Earth observation missions. Possibilities for the near equatorial elements include:

- Testing sensors in space during short duration missions.
- Short duration operational missions. (eg high quality photography).
- Studies of tropical meteorology and oceanography.
- Low latitude resources surveys in support of regional development programmes.

There will also be applications that require orbits or platform capabilities that the Space Station elements are unable to provide and where continued access to free flying satellites is needed. In the Earth observation area many of the missions associated with studies of the solid Earth, with their demands for magnetic cleanliness and/or orbital stability, fall into this category. In a similar way there will be a continuing need for geostationary satellites with their wide coverage and communications capabilities.

Application Priorities

The application of space data covers many disciplines ranging from local through to global in their data and coverage requirements. In defining priority applications emphasis has been placed on those having significant demands on the Space Station system and/or having major scientific or economic potential. In addition to the wide range of applications the user community is also broad, covering both operational users from the commercial, government and science sec-



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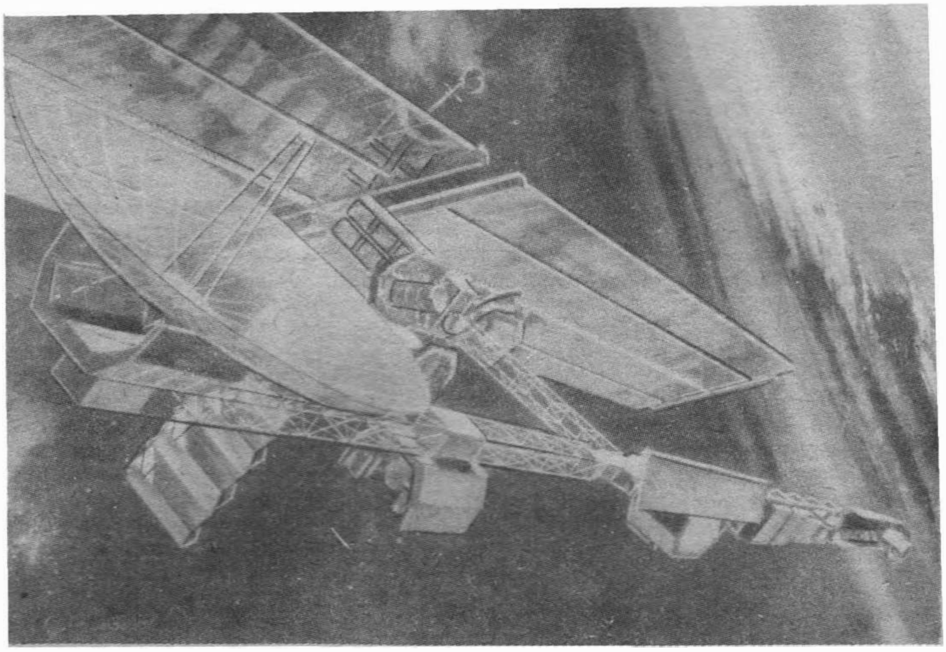
tors, and users from the industry and science principally interested in sensor and applications development. An aim of the Polar Platform designers is to make the system attractive and cost effective to all of these users.

In practice this may not be possible in which case it will be necessary to identify a sub-set of the total requirement that offers the best hope for long term viability. Guidelines on establishing priorities between categories of user need to be developed. One view that has gathered support is that the operational requirement must take priority if economic viability of the Polar Platform is to be achieved. Although there are requirements to test sensors in space, the long servicing interval for the Polar Platform suggests that the co-orbiting or the manned elements of the Space Station would be better suited for this role.

A number of applications require global access to data and may not be viable at all without a space dimension. International programmes concerned with understanding how the Earth operates as a system are already customers for satellite data. The Global Atmosphere Research Programme (GARP) paved the way, and more recently the World Climate Research Programme (WCRP) with its focus on such areas as ocean circulation and land surface climatology has broadened the scope for scientific cooperation. Looking to the future major new international programmes being planned for the 1990s include:

- The Global Ocean Flux Study (GOFS).
- The International Geosphere – Biosphere Programme (IGBP).

The success of these programmes will depend largely on the availability of satellite data. The Polar Platform with its near global coverage has the potential to become the main source of data for these fundamental studies of our own planet. The skills that enabled Giotto to rendezvous with Halley's comet can now be used much closer to home.



Artist's impression of a possible configuration for a space station platform. *NASA*

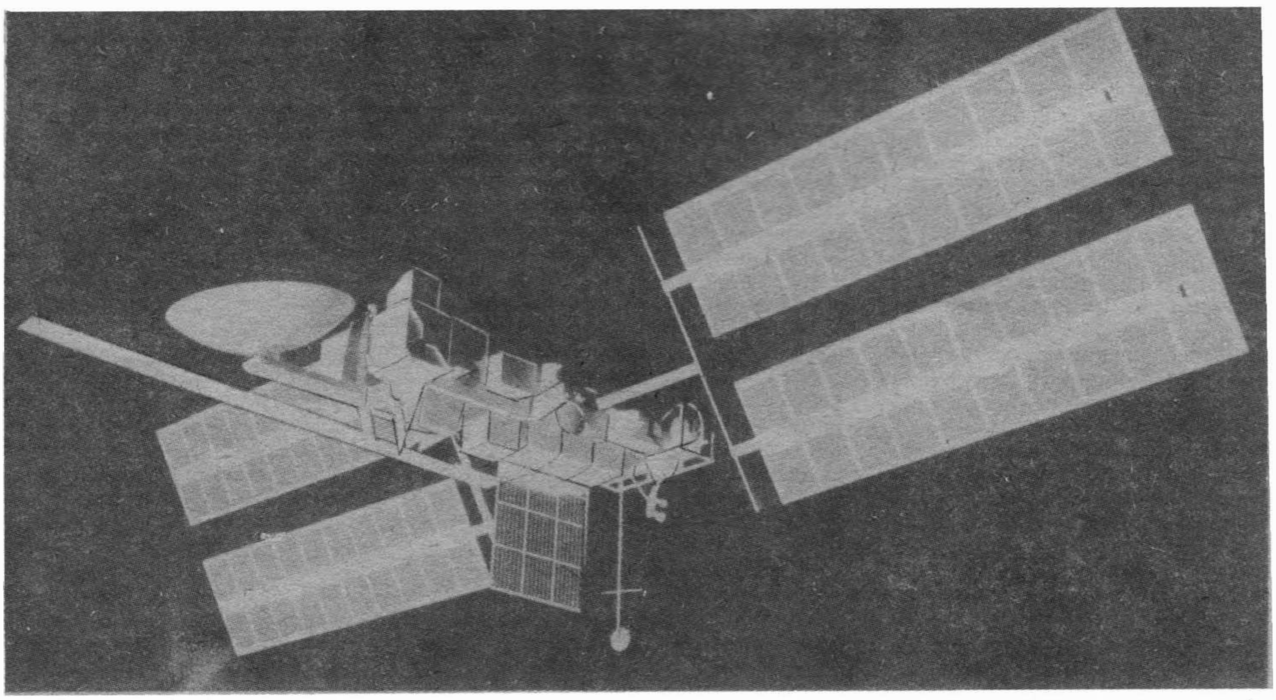
National Sensor Developments

A key question to be addressed is the need for a national sensor development programme to supplement the contributions which the UK is already making to ESA and bilateral sensor programmes. Considerable care is needed to identify sensors that are important in the measurements to be made and yet do not duplicate existing developments elsewhere.

Data Management

There is considerable glamour in building satellites and sensors. The long term benefits and the justifications for a continuing space programme will, however, come from the use of the data acquired. To date only a small percentage of satellite data are used either routinely or in a quantitative sense. This is not only due to the experimental nature of much of the data and the lack of a sizeable user community, but also to insufficient attention being given to data handling and management issues. There are indications that past lessons have been

Model depicting a possible flight configuration of the Columbus Polar Platform. *MBB/ERNO*



learnt and the developments undertaken in the ERS-1 Data Centre could form a foundation for the UK Polar Platform Data Centre.

Data centres such as that planned for ERS-1 are usually limited to "level two" products (single sensor – single pass). In addition, satellite developers sometimes forget that remotely sensed data is rarely enough by itself to satisfy the needs of a particular application. As a result the ground segment development and the establishment of a sound institutional framework needs to be undertaken in partnership with key elements of the user community. It is insufficient merely to set an interface at level two and assume that beyond this a thriving user community is impatiently awaiting remotely sensed data from the Polar Platform. The advantage of a partnership to the Polar Platform ground segment will be the existence of a number of user data centres cooperating with the ground segment owners, and providing a wider range of data products (level three and beyond) including a merging of remotely sensed and other data sets.

Preparing for the Polar Platform

Remote sensing in the UK to date has been largely technology driven. The creation of the British National Space Centre (BNSC) offers a real cpportunity for change and the chance to introduce some user pull to balance the technology push. This has been recognised by NERC (National Environmental Research Council) and has led to the establishment of a Remote Sensing Applications Development Unit to operate within the BNSC.

The success of the Polar Platform will be measured by its ability to serve the operational needs of users. Remote sensing is still largely experimental and qualitative. It is essential, therefore, that in parallel with satellite development an application development and user preparation programme is undertaken. The aims of the preparatory programme are:

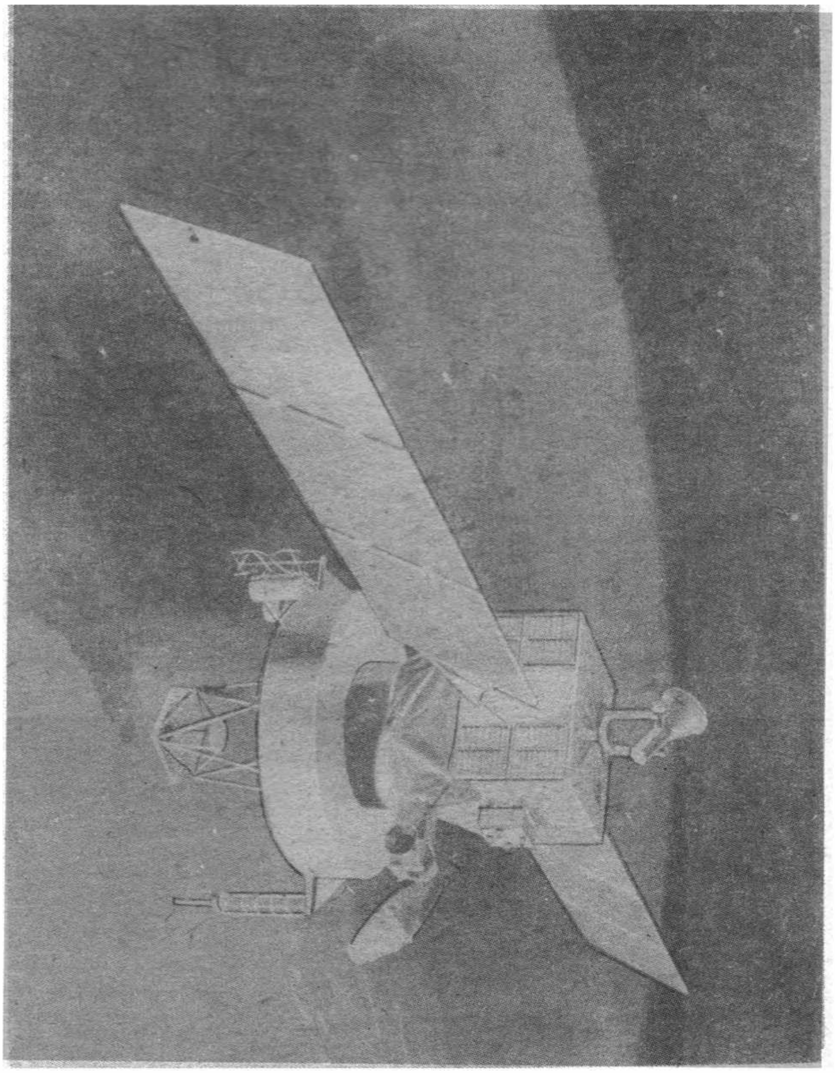
- To undertake the basic measurements that will enable the remotely sensed data to be correctly and objectively interpreted.
- To carry out applications developments and demonstration programmes in partnership with operational users.
- To prepare the user community for the operational use of satellite data (eg training, market development, organisational arrangements).

All three of these elements have been neglected in the past. The UK cannot afford to make the same mistake in the lead up to the Space Station launch. A properly funded and coordinated Preparatory Programme is needed to start now. Activities to be carried out should include:

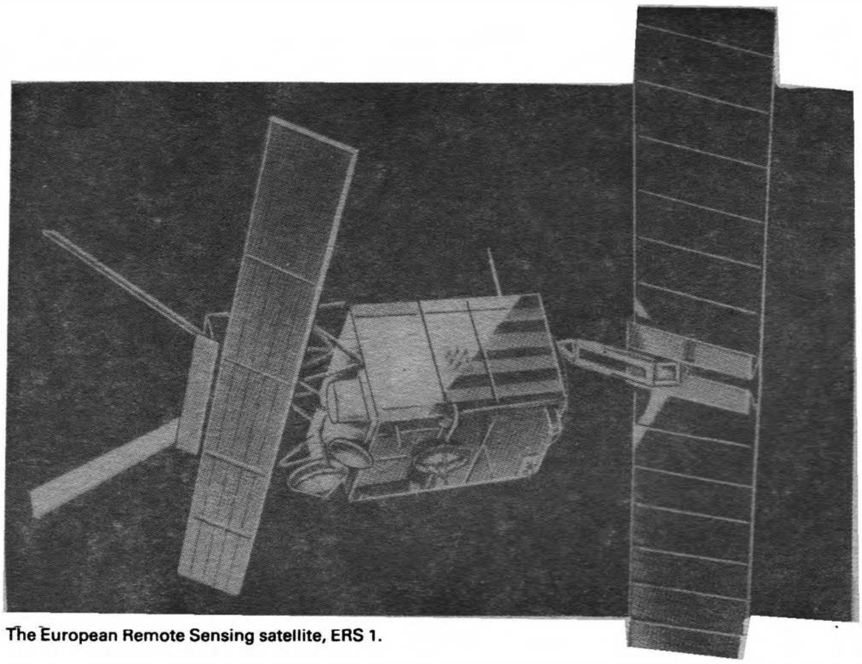
1. Basic ground based measurements aimed at improving the quantitative interpretation of data eg radar backscatter, spectral signatures of natural materials, studies of seasonal variations.
2. Definition of measurement requirements for new sensors including the associated validation and calibration activities.
3. Development of improved information extraction methods eg image processing, data integration, algorithm developments, sampling strategies, correction of atmospheric influences on remotely sensed data.
4. Experimental and pilot projects based on aircraft data and data from existing satellites.
5. Application development and demonstration programmes in partnership with users.
6. Education and training.

Many of the applications of remote sensing are to be found overseas linked with development projects or international science programmes often concerned with global issues such as ocean circulation and climate. The UK needs to participate fully in these overseas activities and the Preparatory Programme with its emphasis on applications development and scientific cooperation should provide the vehicle to achieve this.

The various elements listed above



The joint US/French Topex/Poseidon satellite which will measure sea-surface topography to provide data for models of ocean circulation.



The European Remote Sensing satellite, ERS 1.

tions development and the organisational structures needed for the operational phase of the programme.

The ESA Earth Observation Programme provides a basic foundation for the future and comprises a number of cornerstone missions (see ESA SP-1073, 'Looking Down – Looking Forward' for details):

- Continuation and improvement of observations of the atmosphere.
- Continuation and improvement of ocean and ice observations (ERS-2 and beyond).
- Optical and all-weather land observation.
- Exploitation of precise measurement techniques for solid-earth research applications.
- Payloads of opportunity.

need to be carried out in the framework of a national Polar Platform Preparatory Programme. In parallel with these scientific and technical developments, steps are also needed to establish the organisational framework required to ensure the continued operation of the Polar Platform. The financial resources needed to support the preparatory programme are not insignificant and it does not seem inappropriate to allocate some 10 per cent of the development costs to this crucial task.

A Way Forward

The arguments outlined above have indicated the potential of the Polar Platform to meet the Earth observation needs of users in industry, government and science. This potential will, however, only be realised if hard decisions are taken that will enable a cost effective platform to be built and operated. The main missions for the polar orbiting element of the Space Station will be in the area of Earth observation. The investments made in space hardware must be balanced by appropriate efforts in applications development and exploitation. The sensors to be flown will be new and considerable underpinning research is needed if operational use of the data is to be achieved. The challenges to be faced are not so much in the Space Station infrastructure but in the areas of payloads, data management, applications development and the organisational structures needed for the operational phase of the programme.

The ESA programme outlined above must be complemented by vigorous national contributions. A strong UK national programme is needed coordinated by the BNSC and a four prong attack is recommended:

i) A Polar Platform Preparatory Programme comprising: applied research aimed at developing applications from current and new sensors to be flown; experimental campaigns and sensor validations; applications demonstrations as one component of a broad user awareness programme; systems for data handling and enhanced support for data analysis and management.

Britain from Space – An Atlas of Landsat Images

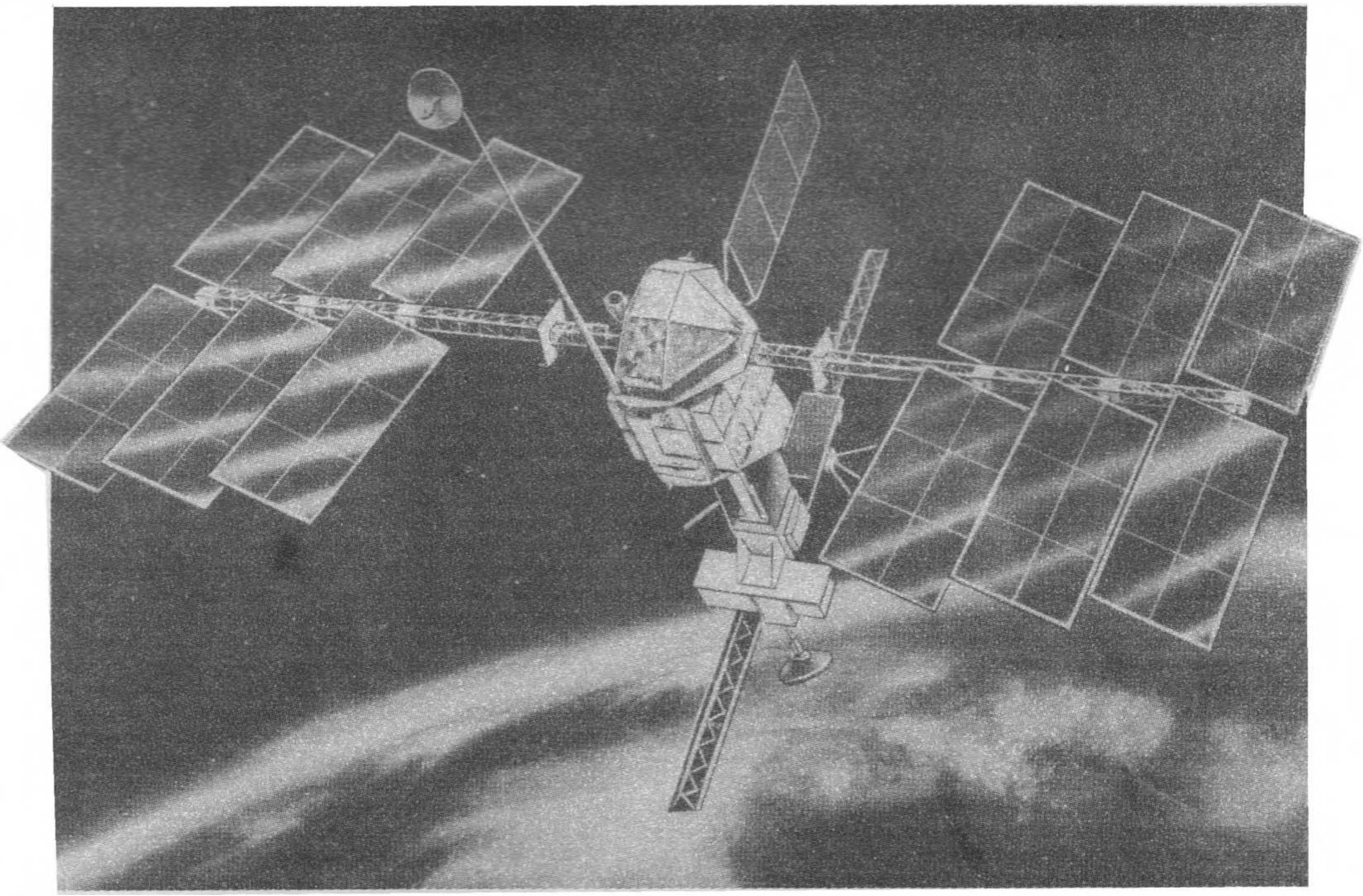
Eds. R.K. Bullard & R.W. Dixon-Gough. Taylor & Francis Ltd., 4 John Street, London, WC1N 2ET. 1985, £12.50.

The great advantage of this type of atlas lies in the very nature of satellite imagery, used here to provide a systematic coverage of the UK for the first time. It contains far more detail and is far more accurate than a comparable map made to similar scale.

The images within this atlas fall into three sections. The first and main group features a systematic coverage of the UK, the second contains specialised Landsat images to illustrate the variety of natural and man-made features depicted, while the third gives examples of other satellite images to show differing techniques and applications.

The Landsat images were generated from a mosaic produced by the National Remote Sensing Centre at Farnborough. Atlas images have been reproduced on a scale of 1:500,000, in simulated natural colour, which is the one most popular with a wide range of users. Eight special geographical images are included to the scale 1:100,000.

Each image is accompanied by an interpretative map, compiled directly from the satellite picture, and a short descriptive text which describes the more important features shown. The atlas also includes an introduction to techniques and hardware, a glossary of terms and a directory of manufacturers and research institutes.



British Aerospace Polar Platform concept

A consistent level of support is needed if the UK is to benefit in full from its investments in the Space Station. Because of the key role that remote sensing will play in the Polar Platform it is suggested that the Preparatory Programme is funded at a level of 10 per cent of the overall UK contribution to the Space Station programme.

ii) A national sensor development programme based on identified requirements and priorities. Candidate sensors are:

- Medium resolution (250-500m) optical imager combining and improving on the qualities provided by the AVHRR and ocean colour sensors. Such an instrument would have broad applications appeal but may need developing bilaterally with the USA.

- Passive microwave radiometers for surface and atmospheric measurements. Significant gaps exist in European capabilities and the UK has the opportunity to make a significant and original contribution.

- Radar altimeters for ocean, ice and land applications. Altimeters have demonstrated their ability to provide accurate and quantitative data and scope exists for the development of second generation instruments.

- Sensors to support other payload elements (eg along track cloud detectors, sensor for atmospheric corrections) providing low cost and high value contributions to the Polar Platform missions.

Considerable care is needed in selecting and specifying sensors for national development, with decisions based on both technical and user related considerations. The national programme must, however, include a sensor development component.

National decisions on sensor developments will need to be coordinated with developments carried out within ESA and where possible with developments undertaken in Europe and NASA. The scope for bilateral agreements on sensor developments will need to be explored.

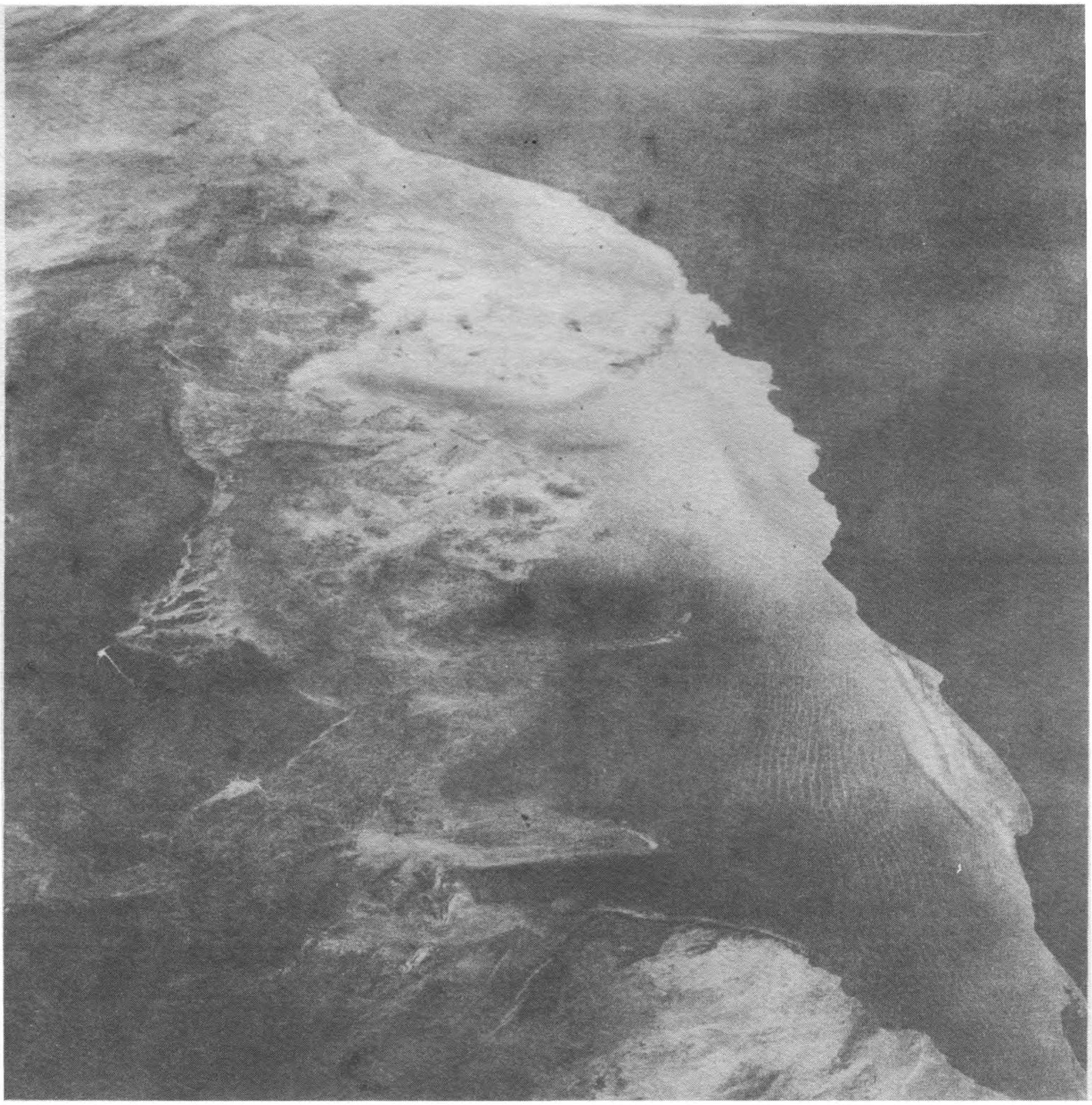
iii) Remote sensing generates enormous quantities of data and the analysis and management of data are crucial to the successful exploitation of the Polar Platform. The UK should take the lead in defining and providing the data management facilities needed for the programme using the ERS-1 Data Facility as the starting point. Links with user based data centres will need to be included.

iv) Institutional arrangements are the cement that ties together the ESA and national elements. To date little thought has been given to identifying the preferred ways to operate and manage the Polar Platform in space including the ground segment. There is scope for UK initiative here and an evaluation of options is needed. It is proposed that:

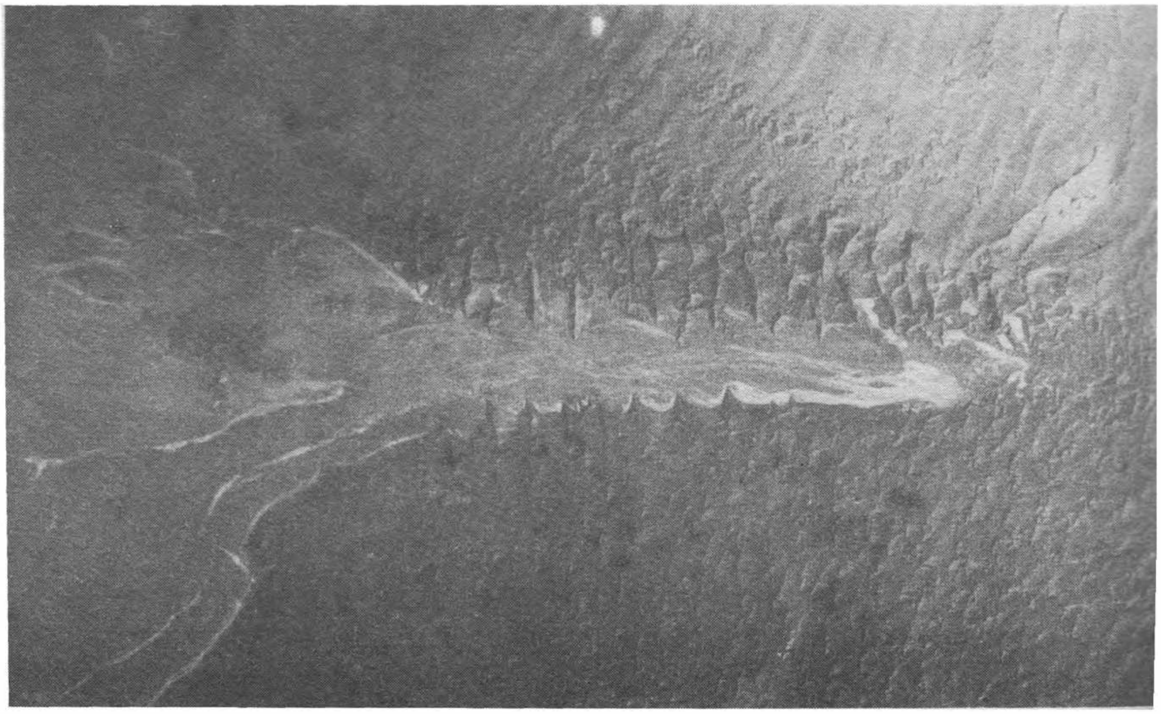
- BNSC take the lead in identifying the options for the orbital and ground segment operations of the Polar Platform.
- A national workshop is organised with representatives from industry, the financial sector, government and users with the task of recommending the preferred solution for the Polar Platform institutional arrangments.
- A UK led proposal is made to ESA.

It is not unfair to say that remote sensing as a technique is still far from fulfilling its potential. The past emphasis on data acquisition and one-shot programmes at the expense of understanding information content and providing continuity of data has only served to delay its wider acceptance by the operational community. The Polar Platform offers an opportunity to overcome past problems but only if a balanced approach is adopted with the proper attention given to application development and preparing users to take the lead in the exploitation of the Polar Platform for Earth observation missions.

*The above article is based on a presentation given by the authors at the British Interplanetary Society's **Space '86** conference in Brighton, September 1986.*



The Namibian desert (above) as seen by astronauts on Shuttle mission 51I. It is one of the driest places on Earth. Right: a close-up showing sand dune formations in Sossus Vlei, part of the same area. *NASA*



NASA'S SHUTTLE EARTH OBSERVATION PROJECT

Photography from Orbit

by Pat Jones

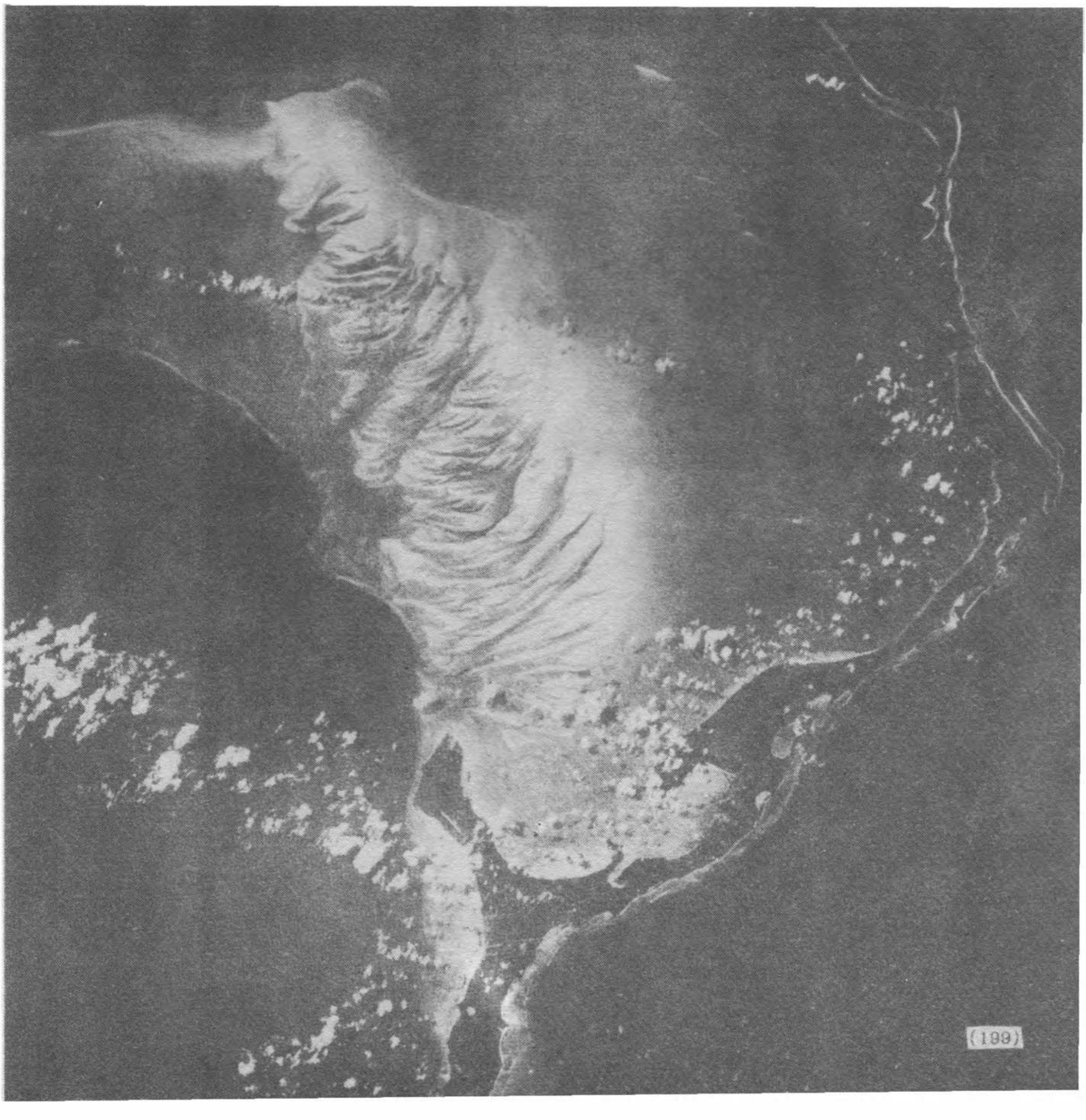
Remote sensing satellites are lauded as one of the great developments of the space age, yet remote sensing where astronauts are present to select the subject matter receives comparatively little publicity. John Young and Bob Crippen returned 551 photographs of Earth from the first 54 hour Shuttle mission in April 1981. Since that historic flight, NASA has accumulated some 30,000 photographs of the Earth taken by Shuttle astronauts.

Each Shuttle mission carries NASA-adapted 70 mm Hasselblad cameras and five flights have also carried the larger Linhof camera which produces large format transparencies. Unlike the false coloured 'images' from remote sensing satellites, Shuttle astronauts bring back natural colour photographs which are often stunningly beautiful. England's "green and pleasant land" appears a bluish green when observed through the atmosphere. By contrast, the range of colours in deserts is spectacular. Australian deserts look red and pink, while the Namibian desert is a rich orange peppered with regimented sand dunes.

NASA devised the Shuttle Earth Observation Project to streamline the collection of 'out the window' photographs from space. Shuttle photographs of Earth can make an excellent introduction to remote sensing. If the frontiers of exploration are in space, it is important to be familiar with the global appearance of our planet as seen from space. However, manned ventures into space have also reminded us that there is a lot we do not understand about our home planet.

From orbit, Shuttle astronauts gave the first reports of four volcanic eruptions and captured numerous examples of industrial and agricultural pollution. Astronauts have reported that they can almost "see" plate tectonics in action – visualising from orbit the Himalayas being forced higher and higher by the continental collision of India and Asia, or imagining the margins of the Red Sea being forced wider apart.

From Shuttle orbit (130 to 380 miles)



White beaches and the heavy white line of an airport runway are two distinguishing features on this photograph of the Bahamas taken by STS-1 astronauts.
NASA

The great peaks and massive system of glaciers of the Karakoram Range in northern Pakistan are clearly visible in this mission 51F view. The area is just to the west of Mount Godwin-Austen with peaks up to 26,000 feet. The Hispar glacier is at the lower right *NASA*

there is the opportunity to take photographs at oblique angles as well as from directly overhead (Landsat provides only overhead views from an altitude of 573 miles; Spot at a similar altitude can acquire views up to 27 degrees either side of vertical). Oblique views can be a valuable introductory teaching tool since the greater relief available with an oblique view in low sunlight can be much easier to understand than an overhead view.

An onboard computer alerts crews when a site of particular interest to NASA scientists is coming up but astronauts also take lots of pictures of views that simply inspire awe or curiosity. Until the STS-1 crew took the accompanying photograph of the Tongue of the Ocean in the Bahamas, no one was really prepared to believe that the production of oolitic limestone in shallow waters on the edge of the continental shelf was so readily visible.

When oceanographer Paul Scully-Power flew on Mission 41G he was able to view the intricate patterns of waves and water boundaries that had been seen in photographs from earlier missions. From his window on the world 200 miles up, he could watch the water forcing its passage from the Mediterranean through the Straits of Gibraltar and then fanning out again as it reached the Atlantic. These wave patterns stand only two or three centimetres high – they cannot be detected by ships or spotter aircraft, but with oblique sunlight on the water, they are unmistakeable from space. The work done by Paul Scully-Power indicates that the relationship between oceanic water circulation and Earth's weather systems is much closer than previously understood.

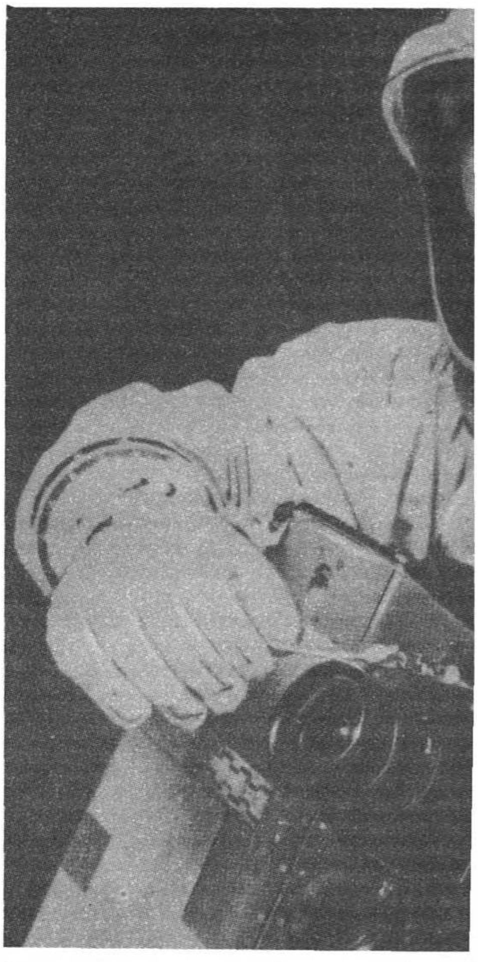
While planetary probes explore the distant reaches of our Solar System, Shuttle astronauts have been helping scientists explore remote and still little known regions of our own planet. Extensive geological interpretation of the high Tibetan plain has been undertaken using Shuttle Earth Observation photography – astronauts have provided many stereo pairs of volcanoes in the Andes for a geologic mapping project. It is sobering to remember that while we have extensive and detailed maps of parts of the Moon, Mars and Venus we do not have a similarly comprehensive map of the Andean volcanic chain!

Shuttle crews and their cameras have been effective in monitoring the environmen. They see ugly oil slicks revealed in oblique sunlight and they can track individual oil tankers bilging their tanks for tens of miles. Vast expanses of desert scenery are interrupted by extensive oil fields and in oil-rich countries expensive experiments in desert cultivation are eye-catching from space. The presence of Humankind is evidenced by the straight lines to which we are addicted – motorways taking the most direct route from A to B, cities laid out in formal grids, and, most easy to spot, the runways of airports. Near large cities photographs often include the straight contrails of departed jets. More surprisingly, many international boundaries are defined as clearly as the Berlin wall when viewed from space. Economic and ideological differences are reflected in agrarian concepts; a land use or field pattern change along a boundary looks, from space, as distinctive as the straight political boundary lines on cartographic maps.

The smooth curves of wave and cloud patterns form a stark contrast with Man's straight lines. Up to 25 per cent of the photographs brought back by each Shuttle crew are of clouds. Unlike black and white weather satellite images, three-dimensional full colour photographs of clouds are both fascinating and instructional. Tropical thunderclouds rising 60,000 feet into the troposphere have grandeur and majesty. Pairs of typhoons dancing across the Pacific look graceful as they execute an atmospherically choreographed formation – an appearance which stands in stark contrast with the devastation which may result from the storm below.

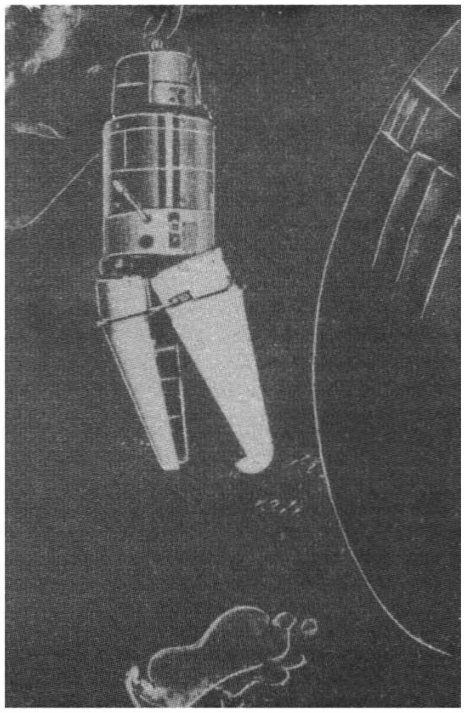
From low-Earth orbit we can look at the Earth as a global ecosystem, observing the interaction of atmosphere, landmasses and oceans. It is a new perspective from which we will learn many lessons and we can also expect a few surprises.

Astronauts receive training in photographic techniques and camera operation *Hasselblad*



The Camera in Orbit – 25 Years of Hasselblad

Earlier this year NASA celebrated the 25th anniversary of the United States' first manned space flight – the launch of astronaut John Glenn on February 20, 1962. It was also in 1962 that cooperation first began between NASA and Victor Hasselblad. The first Hasselblad camera in space was the one that accompanied Walter M. Schirra Jr. on his eight circuits round the Earth during October of that year in a Project Mercury Space Capsule. The flight lasted nine hours 13 minutes. Since then, United States astronauts have carried Hasselblad cameras on every manned space flight.

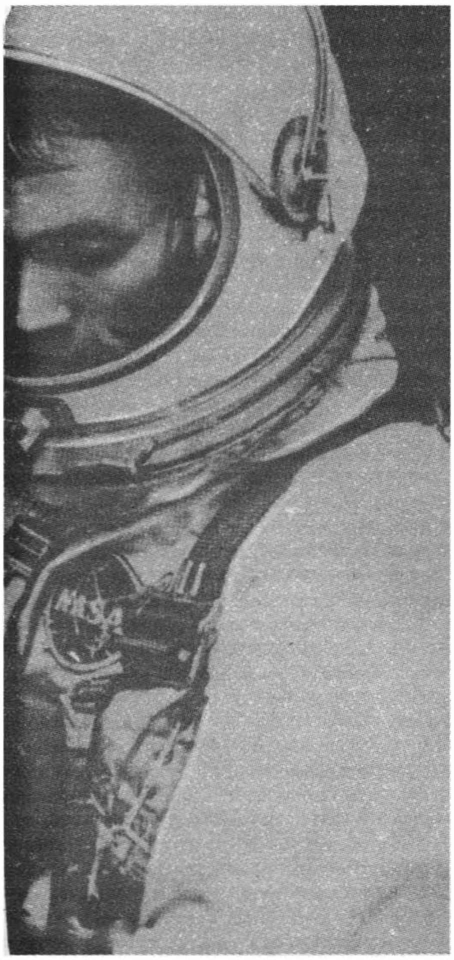


Protective shields still partially in place prevented Gemini 9 astronauts carrying out a practise docking manoeuvre with this rocket stage. *Hasselblad*

The choice of a Swedish camera was one that drew considerable attention because it was a choice made in breach of one of NASA's basic rules, namely, that only equipment that had been made in the USA was to be used in the space programme.

In July 1966 Thomas P. Stafford and Eugene A. Cernan were sent up in Gemini 9. In addition to carrying out scientific experiments and taking photographs of the Earth's surface, their tasks also included a docking manoeuvre. The plan was that they should link their craft to a rocket stage that had been sent into orbit earlier.

However, the manoeuvre could not be carried out because the docking mechanism in the rocket stage was blocked by the protective shields which had failed to open properly. The crew of the spacecraft took 50 photographs of the contrary-minded rocket stage and this documentation very quickly enabled the technicians to analyse the fault. As for the rocket stage, it was nicknamed the Angry Alligator, for reasons which are not hard to see when you look at the pictures of it.



About a month later, the opposite happened – this time it was a photographic fault. During the course of a 25 minute space-walk outside the Gemini 10 capsule, astronaut Michael Collins was supposed to photograph a docking manoeuvre. After taking 130 pictures he lost his Hasselblad Superwide camera. Its loss was Sweden's gain – the first Swedish space satellite was now in orbit! However, the loss of the pictures was a considerable setback for NASA.

On July 20, 1969 Neil Armstrong stepped onto the surface of the Moon. Unfortunately there were no Hasselblad owners there waiting to record the moment but immediately afterwards Armstrong took a picture of his first footprint. It is a photograph that has been published in the press all over the world, in scientific literature and school textbooks. The wealth of pictures from the first Moon flight and the six that followed is overpowering, both insofar as their subject-matter and their multiplicity are concerned. When the last astronauts left the Moon they left behind them eleven Hasselblad cameras (it may have been 12 or 13, the actual total has never been confirmed) and a large number of lenses.

The USA ended its space programme for the 1970's with the launch of the Skylab Research Station. Each of the series of three Skylab crews took Hasselblad equipment including cameras, several lenses each, and film magazines.

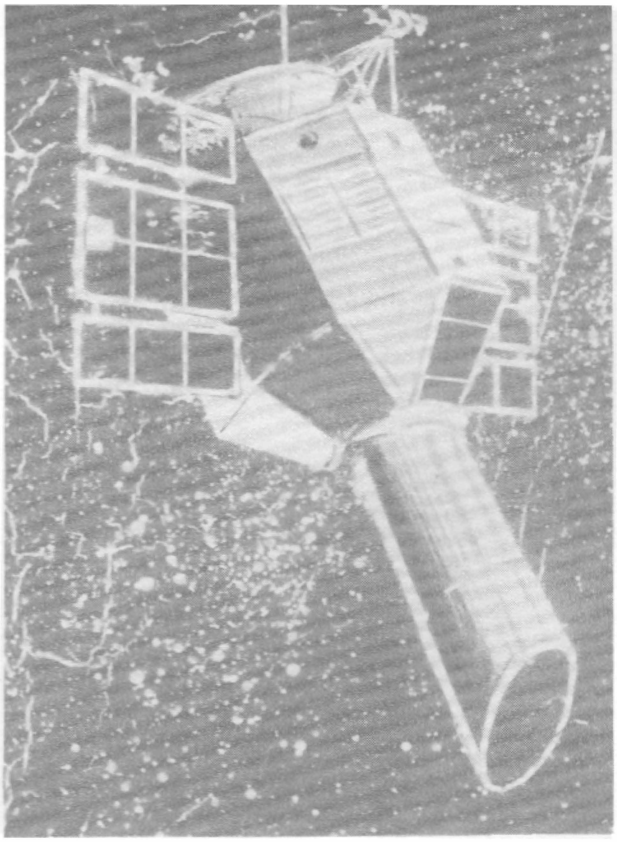
NASA's space activities in the 1980's started with the launching of the Space Shuttle Columbia into orbit round the Earth on April 12, 1981. The Shuttle's greater capacity has meant that there is room to carry out more scientific experiments than on earlier flights. It has also meant that restrictions on the weight of camera equipment have now been removed. The Hasselblad cameras used on the Space Shuttle are standard products, just like the ones used on Earth. Working from their circuit some 270 km up, these cameras have mapped out large areas of the Earth's surface. Much of the area photographed has been recorded on 64 ISO transparency film and some parts on infrared colour film. Each flight has produced a crop of many thousands of very high quality pictures.

Hasselblad magazines are used to record data which describes the flight and gives the date, the time of day and the serial number of each exposure. The data appears outside the frame of the photograph, in the space between the perforations and the edge of the film.

One of the assignments for Shuttle astronauts when flights resume is to make a photographic record of certain areas of the Earth's surface. A team of scientists specify the areas to be photographed, train the astronauts before take-off and will keep them supplied with relevant information during the flight.

Before each flight a Shuttle crew receives training in basic photographic techniques. Each of them is given a manual which lists places of special scientific interest and they are also instructed in the principles of geology, oceanography and meteorology. Pictures taken on earlier manned space flights play an important part in every aspect of this training and using them it is possible to point out interesting terrestrial formations and to teach the astronauts to recognise important features or occurrences of which scientists wish to possess photographs.

Once the crew of the spacecraft has safely returned, the film is developed and the pictures are evaluated and classified. A catalogue is created, with a description of every photograph taken, inter alia in terms of geographical locations. The catalogue also gives details of the camera, the focal distance of the lens and the type of film that was used.



SUPER

The explosion of a supernova in the Large Magellanic Cloud (LMC) on February 23, 1987 has been linked by some scientists to the formation of a black hole.

Supernova 1987A had reached fifth magnitude when first observed from southern latitudes and expectations were that it would brighten much more. However, it reached only magnitude 4.0.

The detection of two bursts of neutrinos emitted by the explosion at an interval of five hours caused much additional excitement. Normally astronomers would expect to detect neutrinos emitted only at the instance of explosion.

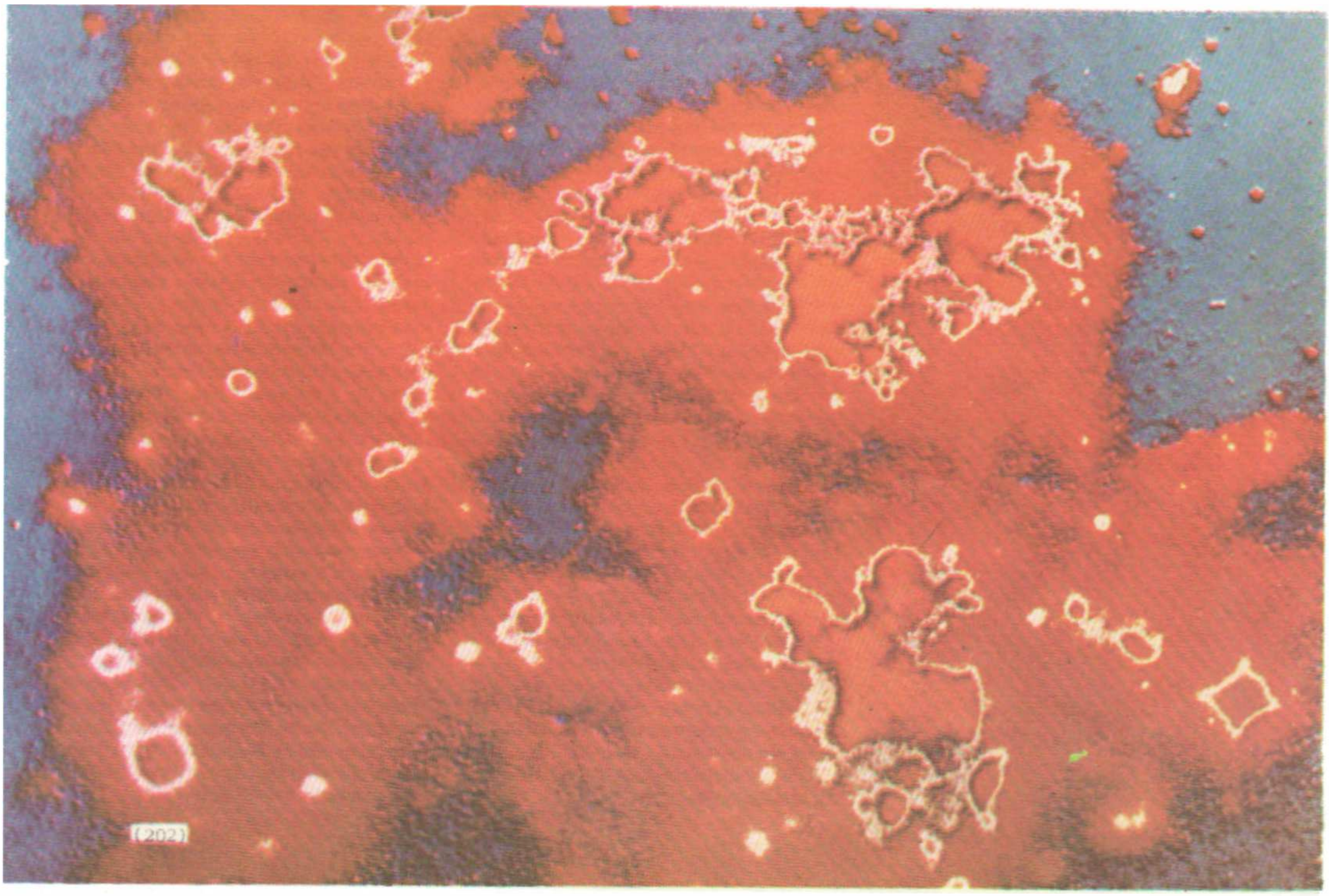
The neutrinos and other elementary particles came from the collapsing heart of a massive star (possibly a red super, super giant) as its core was compressed by gravity to become a dense neutron star.

German Scientists now say that if the neutron star was unstable it could have led to the formation of a black hole, accounting for the extra burst of neutrinos.

Two spacecraft, the International Ultraviolet Explorer (IUE) launched in January 1978 and the Japanese Ginga X-ray satellite launched in February of this year (***Spaceflight***, March 1987, p.95) were turned towards the supernova.

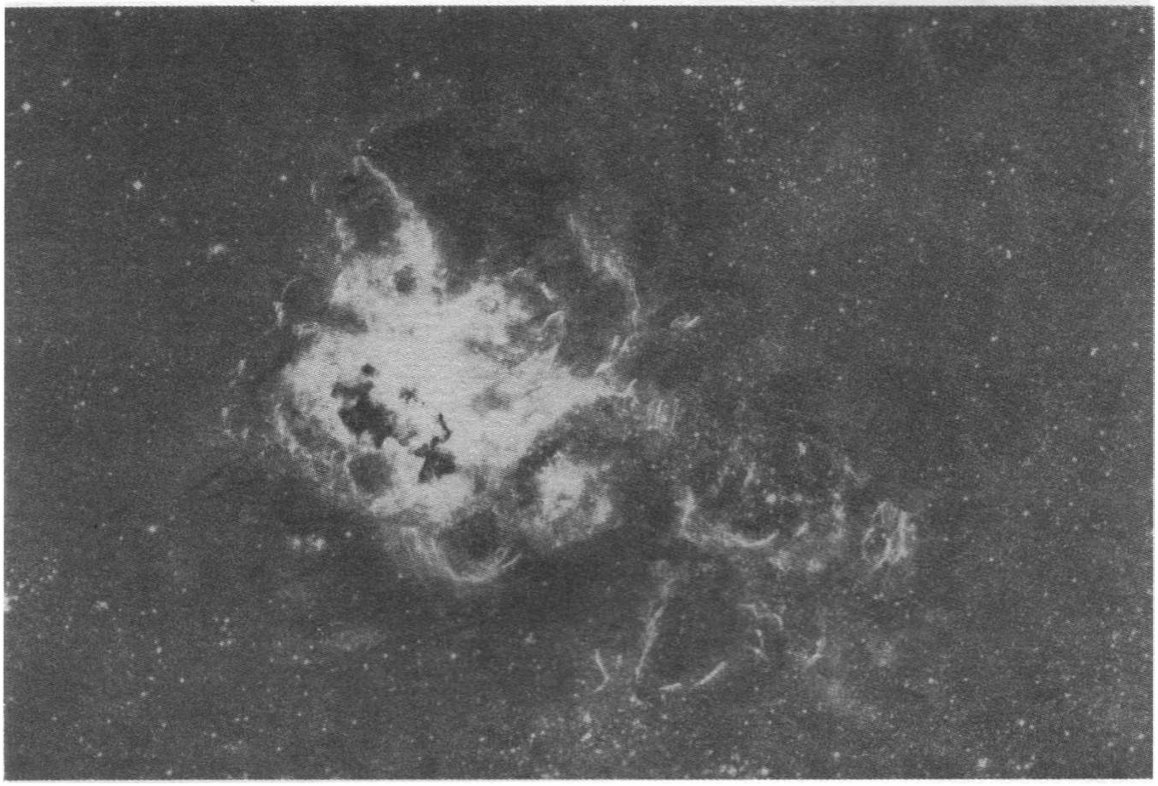
The supernova has been studied almost continuously by the International Ultraviolet Explorer (pictured above). The spectrum was originally different from that of any supernova previously observed but on February 26 it resembled that of a typical Type 1 supernova – low mass white dwarf that accretes matter from a close companion until its mass reaches the critical limit and explodes *ESA*

In 1972 a far ultra-violet camera/spectrograph specially developed by the US Naval Research Laboratory was carried by the Apollo 16 astronauts to the moon where it was used to obtain images unimpeded by the obscuring layers of the Earth's atmosphere. Below is a far UV (1216 Angstrom) record of the Large Magellanic Cloud, the nearest external galaxy to our own. The original exposure was on special black and white film and this colour 'enhancement' was produced by photographic means The camera recorded hot, young stars and highly excited gaseous nebulae emitting strongly at the far UV wavelengths. *Space Frontiers Ltd*



NOVA

Double Burst of Neutrinos Leads to Black Hole Theory



This pair of photographs, obtained with the UK 1.2m Schmidt Telescope in Australia, show the fourth magnitude supernova near the Tarantula nebula in the LMC (bottom picture) and the same field (above) taken four years before the outburst. The supernova was recorded at 10:12:51 UT on February 27 Both photographs were 15 minute exposures through a red filter.

BOOK NOTICES

Halley's Comet and the *Principia*

P. Lancaster Brown, Aries Press, 10A St. Peter's Road, Aldeburgh, Suffolk, IP15 5BG. 1986, £12.95, 349pp.

The mid-1980's marked a unique double event by heralding a new apparition of Halley's comet on the very eve of the 300th anniversary of Isaac Newton's great work the *Principia*.

These two significant milestones in astronomy are inseparably linked in history by a chain of circumstance which began back in 1684 as a result of a forty-shillings wager made at the Royal Society concerning a tricky mathematical problem involving gravity. The young Halley, like others present, was unable to find the proof for it and, on impulse, travelled from London to Cambridge to seek advice from the older and more experienced Newton whom he had met shortly before.

Neither they nor their peers could have foreseen the wide-reaching consequences which followed. Newton, Halley discovered to his surprise, had already solved the problem and, as a direct result of Halley's encouragement, was pressed to write a book setting out his ideas. Before the book reached the public, however, Halley was required to act as Newton's champion, confident, editor and then his publisher, digging into his own pocket to cover printing expenses.

This book describes the remarkable story which led to deciphering the riddle of the comets. It recounts some of the rivalries, petty jealousies and bickerings that beset even great men of science. Along the way one meets many personalities and prodigies of the past including the colourful Sam Pepys, the irascible Dr Hooke, Voltaire and his bluestocking mistress Emilie Marquise du Chatelet.

The second part of the book traces the 2000 year known history of Halley's comet and bring us up to date with the 1985/6 return when it was the subject of world-wide commercial promotion as well as several close encounters by various spacecraft.

Celestial Globe

George Philip and Son Ltd., 27A Floral Street, London WC2E 9DP. £42.60 (plus VAT).

This 30cm diameter globe has been beautifully fabricated on a wooden base. It depicts stars down to magnitude four. The constellations are outlined in schematic form i.e. lacking the various Deities and outlines traditionally associated with star maps, though a variant of the globe is also available depicting the ancient figures for each constellation, if required. About 780 of the brightest stars are named on the globe and many others are identified by the appropriate Greek letters or other designations. The Greenwich meridian, equator and the ecliptic are delineated, the whole being accompanied by a descriptive booklet which explains how the globe can be used, if other than for purely decorative purposes. This provides an introduction to the night sky but contains the statement that only the Orion nebula is visible to the naked eye and that the Andromeda nebula requires binoculars. This, of course, is not true.

A "world clock" disc at the top of the globe can be used to ascertain the positions of the stars at any particular time. This disc should be set so that 12.00 coincides with the meridian of the Sun at the appropriate date. The supporting arm is marked to indicate North and South declination at 10 degree intervals. A further set of lines (meridians) have been added at 15 degree intervals running from the North to the South Pole, each of these 24 lines representing a one-hour time span to correspond with the rotation of the Earth.

The Galaxy and the Solar System

Ed. R. Smoluchowski et al. University of Arizona Press. 1615 E. Speedway, Tucson, Arizona 85719, USA. 483pp. 1986. $29.95.

This volume is full of interesting new ideas and information and, with dozens of maps, charts and graphs, is probably the first to deal specifically with the influence of the galaxy on the solar system, a matter of increasing importance as ideas surface about perturbations of the outer reaches of the solar system by passing stars. Such ideas involve not only the velocities and mass functions of nearby stars but the location and motion of the Sun within the galaxy itself. The relationships betweeen interplanetary and interstellar dust and the distribution of molecular clouds are also closely related. Actually, the region of space near the Sun is relatively free from interstellar material though it could be immersed in a low-density cloudlet.

The general question covered is, therefore, how is our solar system affected by its galactic neighbourhood and, as a closely related spin-off, does our Sun have a companion star, the existence of which might have some bearing on the suggested periodic extinction of many species on Earth?

The supposed companion star, the search for which is underway, has even been given the name Nemesis. Its influence on the planets is assumed to be negligible but could be very significant on loosley-bound collections of material known as the Oort cloud, in which comets are thought to form, and which probably extend to the limits of the Sun's sphere of influence. This makes particularly interesting the recent photograph of the star B Pictoris which shows an accretion disc 'edge-on', extending out to 400 A.U. on either side of the star, where comets are probably being formed in exactly the same way.

Stars, Nebulae and the Interstellar Medium

C.R. Kitchin, Adam Hilger, Techno House, Redcliffe Way, Bristol, BS1 6NX. 1987, 359pp, £35.00 hardback, £15.00 paperback.

This volume describes those characteristics of stars (including groups of stars) and of the material between them which can be directly observed or inferred both from the study of electromagnetic emissions and, occasionally, high-energy particles. Although the result shows a bias towards data which can be collected and examined, the theoretical treatment described is sufficiently detailed to cover all such phenomena.

The product is a comprehensive survey of present ideas on the structure, properties and evolution of stars and of their interaction with the interstellar medium. Special chapters summarise the physical and mathematical background needed for a deeper understanding of some of the more complex processes. For this reason, the text will serve the purposes of most advanced undergraduate courses in astrophysics, though those chapters which are largely descriptive contain material of interest to a much wider spectrum of readers.

The Role of Dust in Dense Regions of Interstellar Matter

Eds. T. Henning and B. Stecklum, Kluwer Academic Publishers Group, P.O.Box 989, 3300 AZ Dordrecht, The Netherlands. 1986. 266pp, $178.00 (£79.00).

This work contains the proceedings of a meeting held in 1986 and is reprinted in hardback from earlier publication in *Astrophysics and Space Science* Vol 128 No. I.

The meeting was devoted to the physics and chemistry of dense regions of interstellar matter and, particularly, with the properties of interstellar dust grains and star formation in those regions.

Dark Matter in the Universe

Eds. J. Kormendy and G.R. Knapp. D. Reidel Publishing Co., P.O.Box 989, 3300 AZ Dordrecht, The Netherlands. 1986. 506pp, £75.75.

This is the first time that the I.A.U. has held a symposium on objects of a totally unknown nature for, even though the mass of the individual particles that make up the dark matter is unknown, in aggregate it adds up about 90 per cent of the total mass of the Universe.

The idea that the Universe might contain much more mass than can be seen in gas, stars and other remnants was pointed out by Zwicky in 1933, who showed that the Coma Cluster could be in equilibrium at the large observed velocity dispersion. For decades since then little was known other than that dark matter existed. There was little systematic informaton about its properties. Only in recent times has progress been made to the point where dark matter and density distributions can be measured. For example, by using accurate rotation curves extending over large ranges and radii, and by decomposing the effects of physical and dark matter, dark matter can be measured and density profiles established.

This volume includes 31 review and invited papers plus 71 other contributions.

History of Rocketry and Astronautics

Ed. R. Cargill Hall, American Astronautical Society, PO Box 28130, San Diego, California 92128, USA. 1986, Part I, 250pp, Part II, 502pp, hard covers $100, soft covers $80.

This volume, in two parts, is the second in a sequence to cover the history symposia of the International Academy of Astronautics from 1967 to date and includes papers from the third to the sixth history symposia.

Part I deals with early solid-propellant rocketry and rocketry and astronautics concepts, theories, and analyses after 1880. Part II covers the development of liquid and solid propellant rockets during the period 1880-1945 and rocketry and astronautics after 1945. Many authors and leading experts in space history have contributed to these volumes, which have numerous illustrations and references.

Stellar Populations

Eds. C.A. Norman *et al*, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 245pp, 1987, £20.00.

This book collects together a number of review papers presented at a symposium in May 1986 and thus provides a comprehensive summary of our present understanding of the stellar populations within galaxies. Material covered includes the initial mass function and star formation histories, the chemical history of galaxies and their observed evolution as a function of redshift and stellar kinematics, and the modelling of synthetic populations.

Any understanding of the fundamental processes which lie at the root of the formation, internal organisation and evolution of galaxies relies, ultimately, on the product of all these activities, the stellar content of galaxies and the ages, positions, dynamic properties and other characteristics which make up what we regard as "stellar populations".

This divides, basically, into two streams of activity. One is a star-by-star-investigation of "resolvable" populations, the other is based on the integrated light studies which have reduced the frontier of observed galaxies with very high redshift very close to the time of galactic formation.

The book thus provides a valuable analysis of the way in which stellar populations help us to understand galactic structure and evolution, an area in which galactic interaction must have played a significant part.

Star Forming Regions

Eds. M. Peimbert and J. Jugaku. D. Reidel Publishing Co., P.O.Box 989, 3300 AZ Dordrecht, The Netherlands. 1986. 735pp. £93.00 (hard cover).

This volume contains the proceedings of an I.A.U. Symposium held in November 1985 which dealt with one of the main problems in present-day astronomy – the study of star formation. It contains 25 review papers and 187 contributed papers.

In the 1940s and 1950s studies of star formation were concerned mainly with the fossil records e.g. star clusters and associations. In the 1960s, models for early stellar evolution established that T-Tauri stars were objects in very early stages of evolution.

In the 1970s, millimetre-wave CO observations provided a powerful new tool to probe directly the raw material of star formation, leading to the discovery that most stars form from giant molecular clouds.

Since then efforts to study star formation have been directed mainly towards probing deeper and deeper into such clouds to seek yet earlier stages in stellar evolution and, eventually, to identify protostars, i.e objects in the process of accumulating their mass of material before actually becoming a star.

Results presented in this work include such topics as the relationship between molecular clouds and star formation, the efficiency and initial function of star formation, collapse and fragmentation of protostellar clouds and large-scale processes of star formation.

Much information is presented for the first time. For example, evaluation of the IRAS satellite data led to the discovery of 247 sources which show colour-characteristics of objects deeply embedded in dark clouds which are probably very young stars of low mass. Many such clouds are examined in detail in the text yet, in some respects, progress in finding protostars has become more difficult. There appeared to be plenty of candidates in the mid-70s: few are left now.

Guide to the Stars

L. Peltier, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1987, 185pp, £6.95 ($11.95).

The late Leslie Peltier was outstanding in the ranks of amateur astronomers, with 12 new comets and four novae to his credit during the period 1925 to 1954 alone. Besides that, his careful measurements of variable stars over a span of some 60 years exceeded 130,000 observations.

Thus, he was well placed to collate the information presented in this book but, contrary to what one might suppose, it is not directed solely to the keen, dedicated amateur. In fact, it actually starts in the most fundamental manner with a description of the night sky and a few well-chosen words on how to find one's way about the stars. Very quickly, however, it goes into the question of augmented vision, beginning with binoculars to obtain a better view. About half-way through, the question of variable stars and novae are inevitably introduced, leading on to Sun and various other objects in the Solar System. Plenty of practical tips are included to enable the beginner not only to become familiar with the sky but to record his observations for the very first time.

It is, therefore, rather more than simply a descriptive work. The urge, right the way through, is to get the reader to go out and enjoy the Night Sky for himself.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

CORRESPONDENCE

Europe in Space

Sir, In recent issues of ***Spaceflight***, I found the detailed articles dealing with the Soviet space programme, the "World Weather Watch", Space at JPL and Satellite Digest most interesting.

Currently there is much going on in Europe. Hermes, Ariane-4, Ariane-5, Columbus are merely the tip of the iceberg. With the Ariane launcher family, Europe is, apart from the USA and USSR, the only space-faring power which has developed its large launchers completely on its own. China's first satellites were launched by an SS-2 rocket and the Japanese began with a Delta.

ARMIN CORDEL
Trier, W. Germany

Space Science and Columbus

Sir, Two lines of doggerel verse run: "In 1492, Columbus sailed the ocean blue". And he found the Americas! To celebrate the five hundredth anniversary of this auspiscious exploratory adventure, an International Space Year is being planned. Further, the USA has invited other nations to participate in an international Space Station for launch in 1992 and beyond, to explore – and exploit – space, the final frontier. Europe's response, now being coordinated by the European Space Agency, is called the Columbus programme. Britain hopes to take the lead in the Polar Platform part of this programme, and also to use other components of the Space Station.

Studies of the Earth's surface from space, termed "remote sensing", will undoubtedly benefit from novel observing systems which require the large mass (about two tonnes) and large volume planned for the Polar Platform (PPF) payload. The large rate at which data can be transmitted back to Earth, some hundreds of megabits per second, will allow high resolution images to be taken in unusual parts of the electromagnetic spectrum. The PPF will be visited for "servicing" in orbit, when instruments may be refurbished or replaced; however, the interval between services is not yet definite.

Perhaps 300 kilograms of the multidisciplinary PPF payload may be taken up by those involved in solar-terrestrial physics (STP), that is in studies of the Sun and the near-Earth space environment. The Polar Platform, in polar orbit at an altitude of just over 800 kilometres and reaching latitudes in excess of 80 degrees North and South, is an excellent platform for mounting instruments to investigate the Earth's upper atmosphere, ionosphere and magnetosphere, as a coupled system, and on a global scale.

A hundred scientists from many European countries and a few from the USA met at the SERC Rutherford Appleton Laboratory last November to consider what would be the best STP experiments to have on the PPF. Visible, ultra-violet and infra-red spectrometers and a pressure-modulated infrared radiometer observing the Earth's atmosphere tangentially could study exotic trace gases such as the oxides of chlorine, hydrogen and nitrogen. These act as catalytic scavengers to destroy ozone in the upper atmosphere.

Natural energetically-charged particle beams, which speed down geomagnetic field lines to cause the aurora, require further investigation at high temporal and spatial resolution. To this end, a Scandanavian-led group proposes an Auroral Imaging Observatory viewing the aurora from above in the visible, ultra-violet and X-ray parts of the spectrum. A French group suggests a synthetic aperture HF/VHF radar on the PPF, probing ionospheric irregularities over the polar cap to investigate convection of the ionospheric plasma driven by the solar wind/magnetosphere dynamo.

A British consortium proposes an array of instruments to observe not only natural phenomena but also the results of active experiments. Here an electron or ion gun is fired from the PPF and its plasma effects are measured on long booms or aboard sub-satellites at variable distances, up to a thousand kilometres from the PPF itself. Operation of the experiment will be interactively controlled in real-time by scientists on the ground, in the so-called "telescience" mode.

The main Space Station, in a 28 degree inclination orbit near 500 kilometres altitude, could be valuable for such active experiments and for investigating the effect of its own enormous structure on the space plasma environment locally, particularly in its wake. It would also be a fine mount for an imaging Fourier Transform spectrometer observing the Sun in the ultra-violet to study such diverse phenomena as mass and energy transport and heating by the waves present in the high solar atmosphere.

Such ambitions plans will clearly be costly; it is important that a realistic, cost-effective long-term programme be drawn up so that as many scientists as possible use the Columbus programme to acquire their results.

Dr. MICHAEL J. RYCROFT
British Antarctic Survey
Cambridge, England

Hotol Take-off Performance

Sir, Having read Bernard Carr's letter (***Spaceflight***, March 1987, p.90) on an air-launch of Hotol I find his idea lacking in engineering reality with the use of a 747. At present the maximum take-off weight allows only 200 tons to be lifted and with the expected weight of Hotol to be 230 tons, there is insufficient safety margin for his proposal to be relevant.

Even were it possible to extend the lift capacity of the 747 to the necessary level there are enormous dangers in the event of unexpected cross winds and turbulence causing the support struts to break and puncture the fuel tanks of Hotol.

As for improving take off performance, may I suggest that inflight re-fuelling is safer as well as more cost effective. Refuelling at say 50,000 feet gives good ground clearance.

J.C.E. MOORE
Essex, England

Equatorial Launch Site

Sir, For many space missions, an equatorial launch site is advantageous. On the other hand, disadvantages are the usually remote location of such places, the lack of proper industrial and other infrastructure; and possible political instability. Cost of preparation and operation is high. So, the pros and cons require careful assessment.

ABMA – later NASA-MSFC – studied (beginning about 1958) the placement of such a spaceport on Christmas Island (1° 52′ N, 157° 20′ W; population ca. 400; 518 km^2; with harbour and aircraft runway available and practically unlimited azimuth). Nearby Jarvis Island (0° 23′ S, 160° 02′ W; 4.1 km^2; no population) might have been useful for dangerous launches. This concept was not pursued very far at that time because of the cost and other aspects.

Other locations were looked at too. DoD joined these efforts and brought in various concepts of 'mobile sea launch capability'. A summary report was published by the House of Representatives, Union Calendar No. 260, Report No. 710, 87th Congress, 1st Session, on July 12, 1961. Its conclusion at this time was "not required".

I am very grateful to my colleague H.H. Koelle, TU Berlin for providing much of the above information.

H.O. RUPPE
Munich, Germany

CORRESPONDENCE

Mr. P.E. Cleator, Founder of the BIS, writes concerning the Society's first members:

Class of '33

Sir, During the first ten weeks of its existence, the numerical strength of the BIS increased no less than threefold. Membership rose, that is to say, from a paltry five to a monumental 15 – the erstwhile Founder Fellows of the Society. For the benefit of posterity, I append, in alphabetical order, the names of these early advocates of the supposedly unattainable:

Askham, C.H.L.	McNab, T.
Binns, H.C.	Raymond, N.E.M.
Chambers, R.S.	Roberts, E.
Cleator, P.E.	Thiele, R. (Senior)
Davies, J.	Thiele, R. (Junior)
Free, J.A.	Toolan, J.
Heaton, A.C.	Weedall, N.
Johnson, L.J.	

I must also place on record that a mere decade and a half later found me lamenting in print that according to the current *Annual Report* and *List of Members,* of those above mentioned, I alone remained actively associated with the organisation, or was at any rate condescending enough to pay his dues.

I advance a number of possible reasons to account for this mass defection. For one thing, the transference of Society Headquarters from Liverpool to London in 1937 necessarily entailed a loss of involvement, and hence motivation, on the part of some members of the original administration. For another, this loss was intensified when, with the outbreak of war two years later, the BIS entered into a period of dormancy for the duration of hostilities, a state of inanimation hardly conducive to the sustaining of interest among its former supporters. And for a third, by the time the conflict ended, several of the founder members, impatient, perhaps, of achieving their interplanetary aspirations during their born days, had departed this life for cosmic destinations unknown.

Such was the situation in 1948, since when the incidence of death-bed defection has inexorably continued, to the extent, so the mathematics of probability suggest, that the band of 15 initiates must by now be close to extinction. That melancholic day, however, is not quite yet, for there would still appear to be one or two of us around. Evidence of this was unexpectedly provided recently when I answered the telephone to hear a voice enquire whether I was P.E. Cleator. On my admitting the offence, the caller then asked if the name Binns meant anything to me, to which I replied that if the accompanying initials were H.C. then it most certainly did.

So it came about, after a lapse of half a century or so, I found myself in conversation with a long lost associate of the early days, now retired and resident in the wilds of South Devon – none other than the Herbert Chester Binns who had placed at the disposal of the emergent BIS its first official meeting place in the guise of a suite of offices on the second floor of Liverpool's No. 81 Dale Street. So far as I am aware, a suitably inscribed plaque has yet to mark this hallowed location, but if, meanwhile, there are any other survivors from among those who gathered there, who have not yet made their ghostly exodus from planet Earth.....

P.E. CLEATOR
Cheshire

Martian Calendar

Sir, I read with interest the article "Martian Standard Time" by Thomas E. Gangale in the June 1986 edition of *JBIS.*

I should point out that there is a fairly extensive prior literature on this subject. Dr. Robert Richardson (one of the first astronomers to risk his reputation by suggesting that there might be something to this space travel nonsense) – wrote an article in the August 1947 Astounding Stories called "A Calendar for Mars." He quotes an earlier paper by Dr. Robert G. Aitken, Director of the Lick Observatory who recommended a sixteen month calendar with 41 and 42 days in alternating years, which would provide a perpetual calendar.

Sometime in the 1950s Dr. Athelstan Spillhaus made a beautiful "Mars Chronometer" which was exhibited in various planetariums. There must be many descriptions of this – perhaps in some early copies of the JBIS.

I touched on one aspect of Martian Chronology in my short story "Trouble with Time", printed in "Tales of Ten Worlds."

ARTHUR C. CLARKE
Colombo, Sri Lanka

SETI and the In Proximity School of Thought

Sir, In SETI and the Mind (*Spaceflight,* February 1987, p.79) W.I. McLaughlin failed to point out why the radioastronomy school of thought regarding extraterrestrial intelligence (ETI) has been assigned low plausibility by many, forcing the in-proximity (IP) school of thought into prominence. The former presumes that the technology of ETI will never advance much beyond what we foresee for ourselves in about two or three centuries – the time typically estimated when we will be embarking on our first interstellar journey via world-ship. The ETI, no matter how many tens of thousands of years advanced over us, would never be able to undertake much exploration or colonisation. Hence, Earth remains undetected by them it is argued, even though roughly a million independently evolved species of advanced ETI are typically estimated to exist within just our own galaxy.

The IP school of thought, on the other hand, allows for continuing breakthroughs and advances in many branches of science, some of them new, and in technology, so that the capabilities of advanced ETI should appear indistinguishable from magic to us (A.C. Clarke's law). It allows for a continuing desire for increased knowledge, and hence in exploration of the galaxy, within any one ETI species for hundreds of thousands of years. It allows for the likelihood that the applied level of ethics of most advanced ETI will be at least somewhat higher than our own. It then follows that Earth has not escaped present detection by ETI, nor escaped past visitations. Various hypotheses have then been put forward in the astronomical literature to explain why we have not been officially contacted by some of these ETI. These include the quarantine, embargo, nursery, laboratory and wildlife-refuge hypotheses. They are overlapping and complimentary, so that several, not just one, may apply.

Thus, with the IP school of thought no special pleading is needed which invokes quickly failing ETI technology in the field of galactic transportation or mobility. No special plead-

ing is needed which invokes a total lack of ETI concern for special treatment of rare emerging societies like ours. Although the IP school of thought predicts that SETI will not succeed, it predicts that interesting events will occur as the embargo is finally lifted.

With the IP school of thought, the epistemology of advanced ETI is seen to be far ahead of human epistemology.

JAMES W. DEARDORFF
Oregan State University
USA

Einsteinian Polycentric Theory

Sir, According to A.T. Lawton ("Copernican Heliocentric Theory", ***Spaceflight***, March 1987, p.92): "Bradley [discovered annual stellar aberration] killed pre-Copernican planetary theories, Bessel [discovered annual stellar parallax] just buried them." If Bradley and Bessel really did so, they did it in vain, because Einstein resurrected these very pre-Copernican planetary theories, and they are alive and well today. This is proven beyond any doubt by the following pasage from A. Einstein and L. Infeld's *The Evolution of Physics* (Cambridge University Press, 1938, p.224):

Can we formulate physical laws so that they are valid for all coordinate systems (cs), not only those moving uniformly, but also those moving quite arbitrarily, relative to each other? If this can be done, our difficulties will be over. We shall then be able to apply the laws of nature to any cs. The struggle, so violent in the early days of science, between the views of Ptolemy and Copernicus would then be quite meaningless. Either cs could be used with equal justification. The two sentences, "the sun is at rest and the earth moves", or "the sun moves and the earth is at rest", would simply mean two different conventions concerning two different cs. Could we build a real relativistic physics valid in all cs; a physics in which there would be no place for absolute, but only for relative motion? This is indeed possible!

Is it not high time, in this space age of ours, that people caught up with 20th century science?

T.S. HARRISS
London

A.T. Lawton replies:

T.S. Harriss raises an interesting view but in quoting the Einstein text he misses the point and confuses Local Frames of Reference (LFR) with Global Frames of Reference (GFR). Whilst the latter may include the former it does not supplant or invalidate it – provided the LFR is used in correct context – which it was in my note about Bradley.

It may come as a surprise that very little in the way of Einstein References need be applied to the Solar System itself. Apart from the motion of Mercury (47 arc seconds/century) and the immediate vicinity of the Sun, most of the Solar System can be accurately treated (for practical purposes) as being ruled by Newton simply because it *is* an LFR.

Only when one starts moving to encompass larger distances does Einstein's GFR become really important. When discussing the origin of the Universe, Einstein's GFR (and its derivatives) are indispensable. Horses for courses!

Incidentally Einstein was not the infallible 'god' so popular to many. He did not believe in Quantum Mechanics and protested that 'God does not play dice'.

To this Stephen Hawking (authority on Black Holes) delivered the famous riposte "God not only plays dice, He throws them into places we cannot even see". In truth, if still alive Einstein would possibly regard much of the work of modern latter 20th century physics as bluntly heretical, and probably would not understand it.

Mir Docking Ports

Sir, I was very interested in your recent article about the Mir space station in the March 1987 issue of ***Spaceflight*** and in particular the photograph on page 105 which shows the forward docking ports. These appear to have replaced the EVA airlock on the Salyuts, so must the cosmonauts use the Soyuz orbital module for "space walks" and if so I wonder why the Salyut stations ever had airlocks? Can any reader enlighten me on these points?

G. COVELL
Tyne and Wear

Soviet 'Star Modules'

Sir, Without getting into facts and figures can someone please help me regarding the similarities of the Soviet Salyut Military Space Stations and the Star/Cosmos Modules?

I have always been quite content believing that the two designs were one and the same, yet to the best of my ability I cannot find a reference to this effect.

Is it all too easy to assume that the Soviet Military Salyuts (i.e. 3 and 5) have been utilised today under the cover designations of Star Modules Cosmos 1267, 1443, 1686?

If this is true, and I believe it is, then we will never see the interiors of these modules as was the case for Salyuts 3 and 5.

If on the other hand I am wrong, please can someone tell me so and I shall thank them now for solving this perplexing question.

LEE CALDWELL
Bristol, England

The following information has been provided by Mr. Rex Hall concerning Soviet module type craft:

Salyut 3 and 5, the so called Military Salyuts, are believed to be designed differently from the modules. Military Salyuts were the forerunners of the modules. In the Kosmonautica Encyclopedia (published 1986, p.438) it was disclosed that Academician N.V. Chelomei was the Designer of Salyut 3 and 5 as well as Cosmos 1267, one of the four module type craft that have flown.

The four modules that have flown to date represent a type of vehicle that has been designed and flown in different configurations to serve several purposes. They are a heavy freighter, a space tug or for use as research or production modules.

Cosmos 929 was a test vehicle to verify performance characteristics.
Cosmos 1267 was in a space tug configuration.
Cosmos 1443 was flown in the heavy freighter mode with a returnable capsule.
Cosmos 1686 was designed as a module to test effectiveness as a multi-purpose orbital module.

The next to be launched will be a module type which will be the Astrophysics 'Roentgen' module to go to Mir. This will be in the same series as Cosmos 1686 (**Ed.** *The Astrophysics 'Roentgen' Module was launched subsequent to the receipt of this letter, see page 183.)*

We have seen only a few photographs and these were very fuzzy photos from the inside of Salyuts 3 and 5. The Cosmos modules have been covered even less in recent Soviet publications and only one picture can be positively identified as coming from a module type craft. A cutaway diagram of Cosmos 1443 – Salyut 7 was released in the Soviet Union magazine and shows much of the design features.

CORRESPONDENCE

Knocking Space

Sir, I support Tony Devereux's concern (***Spaceflight***, April 1987, p.170) for the low standard of uninformed treatment of space in the nation's press. Norman Stone in an article entitled 'Brainless talk about the brain drain' (Daily Telegraph, March 26, 1987) writes:

> *"The enormous sums of money which have gone into the really spectacular pieces of scientific research, such as space exploration, have resulted in only one piece of technology in general use – the non-stick saucepan."*

One day this old 'chestnut' will doubtlessly be laid to rest. But not yet apparently. Space technology is in the process of reshaping the future of the world through global communications, Earth observation, new initiatives in peaceful international cooperation and numerous benefits to medicine and other fields of application. Yet to the general public, the picture so often presented by the media is that of a non-stick frying pan, which apparently is now a non-stick saucepan.

P.R. FRESHWATER
Oxon

Balloon-suspended Rockets

Sir, Dr. William McLaughlin (***Spaceflight***, February 1987, p.79) states that Project Far Side demonstrated the capability of launching a balloon-suspended rocket. Actually, small sounding rockets were launched from high-altitude balloons in August 1952, more than four years prior to the Far Side flights. These so-called rockoons were developed by a University of Iowa group led by Dr. James Van Allen following a suggestion by Lt Lee Lewis, U.S.N. in 1949 [1]. The rockoon was intended to satisfy the need for an inexpensive sounding rocket that could be launched from remote locations. Such a capability was particularly desirable for Van Allen's investigation of the variation of cosmic-ray intensity with geomagnetic latitude.

The development of the rockoon is described in [1]. The vehicle selected was the Deacon, a small solid-propellant rocket capable of reaching an altitude of no more than 100,000 ft when launched from sea level. Tests of a modified Deacon, including launches from a simulated balloon suspension, were carried out in June and July 1952 at White Sands, New Mexico. No actual rockoons were flown due to range safety considerations. The first test series of seven rockoons was launched from the US Coast Guard cutter "Eastwind" near the northwest coast of Greenland. The first two flights on August 21 and 23, 1952 were unsuccessful due to the failure of the rockoon's engine to ignite. A third flight succeeded on August 28, achieving an altitude of 200,000 ft after launch from the balloon at 38,000 ft. Four more successes soon followed, one of which travelled from 57,000 to 295,000 ft on August 29. Each rocket carried a 30 lb payload.

A series of 23 flights was conducted a year later, with launch altitudes as high as 83,000 ft and peak altitudes reaching 340,000 ft. The rockoon then went on to achieve a fair degree of popularity before replacement at the end of the 1950's by satellites and improved ground-launched sounding rockets [2].

JOHN DORSEY
Illinois, USA

References

1. James A. Van Allen and Melvin B. Gottlieb, "The Inexpensive Attainment of High Altitudes with Balloon Launched Rockets" in *Rocket Exploration of the Upper Atmosphere*, eds. R.L.F. Boyd and M.J. Seaton, Interscience Publishers, Inc., New York, 1954, pp. 53-64.

2. William R. Corliss, *NASA Sounding Rockets 1958-1968: A Historical Summary*, NASA, Washington, DC, 1971, p.27.

Shuttle Escape Ideas

Sir, J.S. Anderson's letter published in ***Spaceflight*** (Feb. '87, p.49) asks for comment on the proposal of fitting small rockets on the Shuttle Orbiter's wingtips to "pull the Orbiter away from the stack". I feel this would not be feasible, as stresses produced when the Orbiter attempts to orientate itself for a landing from the "heads-down" position it is in during ascent would break the Orbiter apart. The chances of making a successful return to launch site would be slim or non-existent.

TONY ELLIOTT
Southampton, England

Coat of Arms

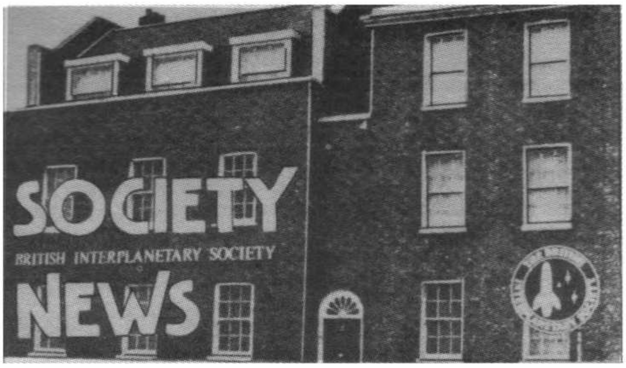
Sir, I wish to extend my congratulations to the Society and especially the Council on the grant of a coat of arms by the College of Arms. The design is both striking and distinctive and will prove an inspiring figure-head to the Society's formal intentions.

The Comet badge is of course most appropriate, and it begs the question does the Society intend to have any lapel or tie pin badges made up to this design? I am sure they would prove popular.

DOMINIC EARL
Plymouth, England

Sir, I have just read the March edition of ***Spaceflight*** and was delighted to find that the Society has obtained a grant of arms. As a heraldic enthusiast, I have always advocated the desirability (if not the duty) of societies such as the BIS obtaining arms, and I would like to congratulate the Council on taking this step. The design is a fine example of English heraldry, I particularly like the design of the arms themselves which successfully combine the traditions of both the Society and heraldry.

C.M. HEMPSELL
Herts



More Space for SPACE

Launch of £80,000 Building Appeal

The Society is running out of space! That is space at its Headquarters Building which it has occupied since May 1979. The Society urgently needs to extend its operations and facilities in support of the rapidly increasing developments in Space with which it is involved.

Planning permission has recently been granted to the Society for an extension to its premises as shown by the shaded area on the diagram on the form below. The project is very modest in terms of the amount of construction work to be undertaken, but . . .

As a non-profit making Registered Charity, the Society expends all its income on services to members and in support of its wider role of promoting space and astronautics internationally. It now asks members, organisations and the public at large to recognise its urgent need for ***'More Space for SPACE'*** by contributing to its £80,000 *Building Appeal Fund.*

The generosity of members and others has been a vital factor in the Society's growth over past years. Yet again we reach another step in the Society's progress which must be taken without delay.

All contributions to the Society are now being allocated to its £80,000 Building Appeal Fund, unless expressly requested otherwise, and construction will start as soon as adequate funds are in hand. Regular Progess Reports on the project will appear in future issues of ***Spaceflight***.

Every extra contribution is one step nearer to the completion of this essential project. Please use the form below or enclose a covering letter with your contribution. The Society will be pleased to send you, if requested, a copy of its newly available Brochure *Guide to Aims and Activities*. Your contribution will be most gratefully received and acknowledged.

EXTRA ISSUES OF 'SPACEFLIGHT'

Arrangements are in hand for the publication of two supplementary issues of *Spaceflight* for the two months of the year (July and October) when the magazine would not otherwise appear.

These issues will be devoted to articles on a range of space topics and provide a valuable addition to the ten regular issues of ***Spaceflight*** which members normally receive. The extra supplements will also conveniently fit into the annual ***Spaceflight*** binders for these are designed to accommodate up to 12 issues.

Those members who have already remitted £4.00 (or US$6.00) for the two issues of *Space Education* in 1987 will now automatically receive the two supplementary issues of ***Spaceflight*** in lieu of *Space Education*, publication of which will be suspended, the last issue being Vol, 1. No. 12, dated Autumn/Winter 1986/7. Articles and reports relating to space education will now be re-allocated to the July or October ***Spaceflight*** supplements.

All other members can secure the July and October ***Spaceflight*** supplements by post by simply writing to the Society by June 15 and enclosing a remittance of £4.00 (US$6.00).

30 YEARS OF 'THE SKY AT NIGHT'

Our congratulations to Patrick Moore, Fellow of the Society, on the 30th anniversary of 'The Sky at Night' TV programme.

The long run of this programme under Patrick's direction speaks volumes for his contribution to public awareness and interest in astronomy and space exploration. Into an essentially astronomical programme, he introduced the new dimension of space research with coverage of the various lunar and planetary programmes.

With the arrival of Halley's comet in 1986, the telescope and spacecraft had a common target and Patrick's musical talent also shone forth with his composition of a march named after the comet. The anniversary is gladly reported by ***Spaceflight*** as Patrick was the magazine's first editor in 1956.

The Headquarters of the Society

"Your generous support will help our building programme to go ahead without delay"

Charity Commission No 250556

Rex Turner, BIS President 1985/7

I have pleasure in enclosing a contribution* towards the Society's Building Appeal of £ $

I would like to receive a copy of the Society's Brochure *'Guide to Aims and Activities'* ☐

NAME ______________________

ADDRESS ______________________

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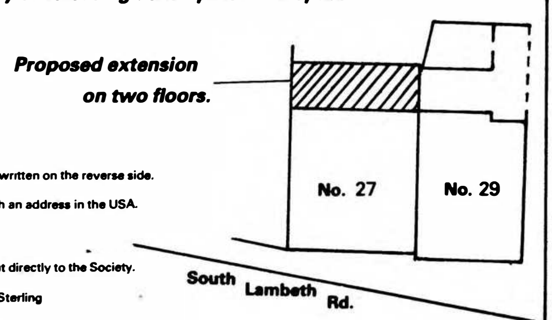
£80,000 is urgently required for an extension to the Society's premises to enable its operations and facilities to support today's increasing developments in space.



*Payments from UK may be made -

(a) By cash, postal order or cheque made payable to 'BIS'

(b) By GIRO. Our GIRO account number is 53 330 4008

Payments from abroad may be remitted as follows -

(a) From Europe the easiestway is by GIRO transfer.

(b) By Eurocheque with the account number written on the reverse side.

(c) By US dollar cheque drawn on a Bank with an address in the USA.

(d) US dollar notes.

(e) Members may instruct their Banks to remit directly to the Society.

(f) US or Canadian money orders payable in Sterling

Send to: The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

MEETINGS DIARY

Society meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address. Members may bring one guest.

29 April 1987 **Symposium**

FUTURE SPACEPLANES

This symposium, which is open to both members and non-members of the Society, will be held in the Conference Room, Millbank Tower, Millbank, London, SW1. Registration opens at 9 am and the symposium will begin at 9.30 am Registration forms are available from the British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

PROGRAMME

Morning Session (Chairman: Mr. G.W. Childs)

Introduction
J. Leeming (BNSC)

History of the Aerospace Vehicle
Dr. E.J. Becklake (Science Museum)

Ariane V/Hermes
(Speaker to be announced)

Hotol Update
Dr. R.C. Parkinson (BAe)

The Two Stage Sanger Space Transport System
Dr. D.E. Koelle & Dr. H. Kuczena (MBB)

Afternoon Session (Chairman: Mr. C.H. Martin)

Improved NASA Space Transportation System:
Flight Resumption Plans
Dr. D. Baker (Sigma Projects)

Titan
R.A. Chamberlain (Martin Marietta)

Japanese Spaceplane Studies
(Provisional)

Jarvis
E. Bandsung (Boeing)

Econometric Systems and Mission Analysis of the NASA Shuttle
Dr. D. Baker (Sigma Projects)

The Soviet Space Shuttle Programme
A.T. Lawton

The meeting is scheduled to close at 17.00 hrs.

6 May 1987, 7-9 pm **Lecture**

REVIEW OF THE SOVIET SPACE PROGRAMME

by P.S. Clark

For more than a decade, in terms of launch rates, the Soviet Union has dominated space activity. Many aspects of its space programme are shrouded in secrecy but a careful study of public information allows insights to be obtained into Soviet space programmes. Phillip Clark has been analysing the Soviet Programme for nearly two decades, and will present a review intended for the non-specialist of recent development and the future direction of the programme.

Admission by ticket only.

10-17 October 1987 **Congress**

38th IAF CONGRESS

Invited lectures, Symposia and over 600 technical papers will be presented. To be held at Brighton, England, hosted by the British Interplanetary Society. To go on the mailing list for free information send your name and address to: "38th IAF Congress", The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

13-15 October 1987 **Exhibition**

SPACE '87

SPACE '87, an International Exhibition of Space Technology will be held jointly in Hall six of the Metropole Hotel, Brighton and in the nearby Brighton Centre. It is open to Society Members and Members of University or Polytechnic Departments on any of the above dates.

Admission tickets will be required for those who are not registered participants at the 38th IAF Congress which will be held concurrently at the same venues. Tickets may be obtained, free of charge, by applying to the Society enclosing a reply paid envelope. Each member of the Society is also entitled to bring one guest, in which event a second ticket should be requested.

15 October 1987

SPACE '87 – Education Day

Teachers wishing to arrange visits by school parties to ***SPACE '87*** on this date should contact the Society.

17 October 1987

Technical Visits

The Society has arranged two all-day technical visits to take place on Saturday, October 17, 1987 as follows:

Tour 1: The National Remote Sensing Centre, Farnborough and the Meteorological Office, Bracknell.

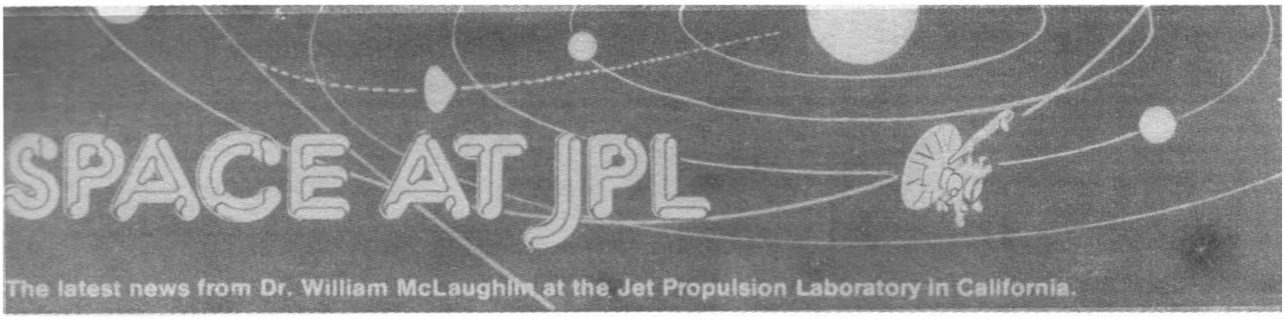
Tour 2: The Rutherford Appleton Laboratory, Didcot and the UKAEA Culham Laboratory.

Each Tour includes the provision of luncheon and transport by private coach to and from Brighton, with a stop on the return journey at Victoria Station for those wishing to disembark in London. The Tours may be joined either at Brighton or at the first organisation visited.

Members of the Society can apply for a place on either of these visits by writing to the Society enclosing the appropriate fee: (Tour 1, £22.50; Tour 2, £17.50). Members who will be attending the 38th IAF Congress should apply on the Congress Registration Form, copies of which are available from the Society. Further details appeared in ***Spaceflight***, April 1987, p.168.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.



Voyager on Target

On March 13 the engine on Voyager 2 burned for 70.5 minutes to set the final course to Neptune for the encounter with that planet in August 1989. The plan to fly closely over the north pole of Neptune was actually implemented in two parts, with the engine being lighted first on February 14, 1986, just after the Uranus encounter, and then on March 13, 1987.

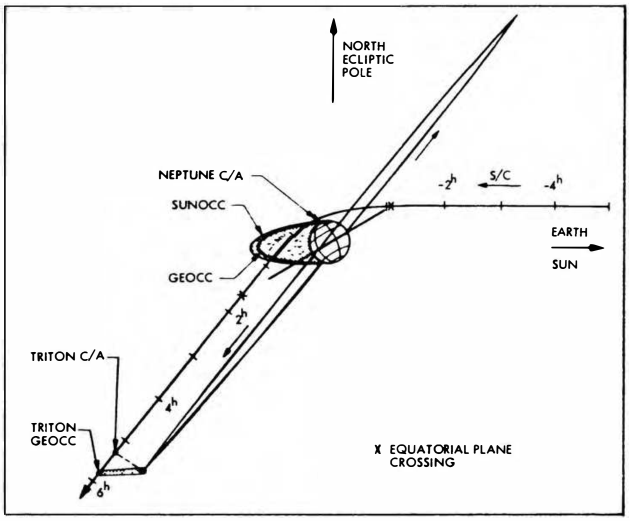
It would have been slightly more efficient with respect to fuel usage to have accomplished the entire course change for the north-polar passage with just one (longer) burn, performed close to Uranus, but the project wanted to hold open its options for the Neptune flyby until a more complete analysis could be performed. As described in the March 1987 edition of "Space at JPL", that analysis validated the north polar passage as feasible and of the highest value to science.

Dr. Donald Gray, Chief of the Voyager Navigation Team, reported that the burn changed the spacecraft's speed by approximately 9.3 m/s and was the largest manoeuvre yet performed by either Voyager spacecraft during an interplanetary-cruise phase (as noted above, larger burns tend to be done near a planet for efficiency's sake – the February 14, 1986 burn changed the spacecraft's speed by about 21 m/s.)

The intent was to advance the arrival time at Neptune by 11 hours 55 minutes and to shift the point of arrival by just over 21,000 km. Precise measurement of the course change will have to await analysis based upon post-burn tracking by antennae of the Deep Space Network. However, doppler measurements of the change in the line-of-sight velocity of the spacecraft and telemetry returned during the burn indicate normal performance was achieved by the propulsion system, so the desired trajectory change will result.

Two course corrections are scheduled for Voyager 2 during the encounter period in order to tune up the trajectory. The first will be about 24 days before closest approach and, using the latest knowledge of the trajectory, will adjust the arrival conditions with a burn of probably a few metres per second. The last burn before encounter, which may be quite small, is scheduled for five or eight days before encounter. The five-day option will be exercised if it is judged that extremely precise targeting is necessary in order to achieve the dual Sun/Earth occulation feature of the mission (see the March issue).

Neptune encounter, August 1989.



New Results on Circumstellar Disks

The Infrared Astronomical Satellite (IRAS) revealed that several of the stars included in its all-sky survey, conducted in 1983, were accompanied by cool, solid material: particles which were at least the size of grains of sand. Subsequently, one of these stars, Beta Pictoris, was photographed from Earth with a 2.5m telescope and showed a disk of encircling material. Recent investigations have uncovered more details concerning the structure of this disk and related ones about other stars.

The view of stars as simple entities was not disturbed until 1783 when John Goodricke explained the regular variations in brightness of Algol by postulating the presence of a darker companion which periodically reduced the total light we see by eclipsing the brighter star. The great astronomer William Herschel published, in 1803, the results of observations which confirmed that several apparently double stars were also dynamically bound and, in fact, were in orbit about one another.

Over the years the subject of stellar systems with more than one component (the Algol system contains three gravitationally associated stars) has flourished theoretically and empirically, yielding such exotic objects as stars that exhange mass with one another.

A new category of stellar attendant became known by the 1960s when the young subject of infrared astronomy brought forth evidence for clouds of dust and gas surrounding certain stars. Measurements at various wavelenghts of the energy output of these

stars showed more than expected in the infrared. This so-called "infrared excess" was attributed to circumstellar material, left over from the process of the star's birth from a cloud of dust and gas, which absorbed radiation from the star and reradiated it in the infrared. The young star was, in effect, wrapped in a cocoon.

The subsequent discovery that in some cases the circumstellar material might be flattened into a disk was not entirely a surprise; in his 1981 book, *Cosmic Discovery,* Cornell astronomer Martin Harwit correctly predicted: "We are on the verge of discovering disks around stars. A picture of a disk star would look somewhat like the planet Saturn with its rings". See the picture of Beta Pictoris in the February 1985 edition of this column.

At the January 1987 meeting of the American Astronomical Society held in Pasadena, astronomers Anneila Sargent, of Caltech (the parent organisation of JPL), and Steven Beckwith, of Cornell University, announced new results with regard to the structure of circumstellar disks. They employed an interferometer, synthesised from three 10.4m radio telescopes, at the Owens Valley Radio Observatory in California, to measure the velocity of gaseous constituents of the disk surrounding the star HL Tauri. The disk of dust surrounding HL Tauri was discovered by Beckwith and his colleagues two years ago. Now, the interferometric measurements have shown that carbon monoxide gas is also present in the disk. This circumstance allows doppler-shift measurements to be made, using discrete emission lines of the gas, and the corresponding inference of the rotational velocities of the disk at various distances from the star (the dust ring emits in a continuum and, thus, such doppler measurements would not be possible for it).

The exciting result obtained by Sargent and Beckwith is that the disk appears to be rotating with a Keplerian distribution of velocities (more rapidly near the star, slower further out), just as exhibited by our planetary system. This does not imply that the HL Tauri disk is planetary in nature – the star is very young and its circumstellar dust grains have been shown to be smaller than those of Beta Pictoris – but the system could be in an early stage of planetary evolution.

At the same Pasadena meeting, a new photograph of the disk of Beta Pictoris was shown by Francesco Paresce and Christopher Burrows, European Space Agency astronomers at the Space Telescope Science Institute. Reflectivity studies showed that the disk is composed of particles larger than the wavelength of red light, so that these particles must have been built up from the much smaller interstellar grains by a process of agglomeration. Modern theories of planetary formation employ agglomeration as a key step in the process.

Indeed, Ben Zuckerman, of the University of California, Los Angeles, showed a photograph of the Beta Pictoris system that provided some indications that comet-like bodies might be present in the disk. It is not known whether planets are now present in the Beta Pictoris system.

Circumstellar disks are an active area of astronomical research, and we can expect a continuing flow of new results, particularly when NASA's Hubble Space Telescope is lifted into orbit. With that instrument, it might be directly possible to image large planets of nearby stars, should those objects exist.

Space Microelectronics

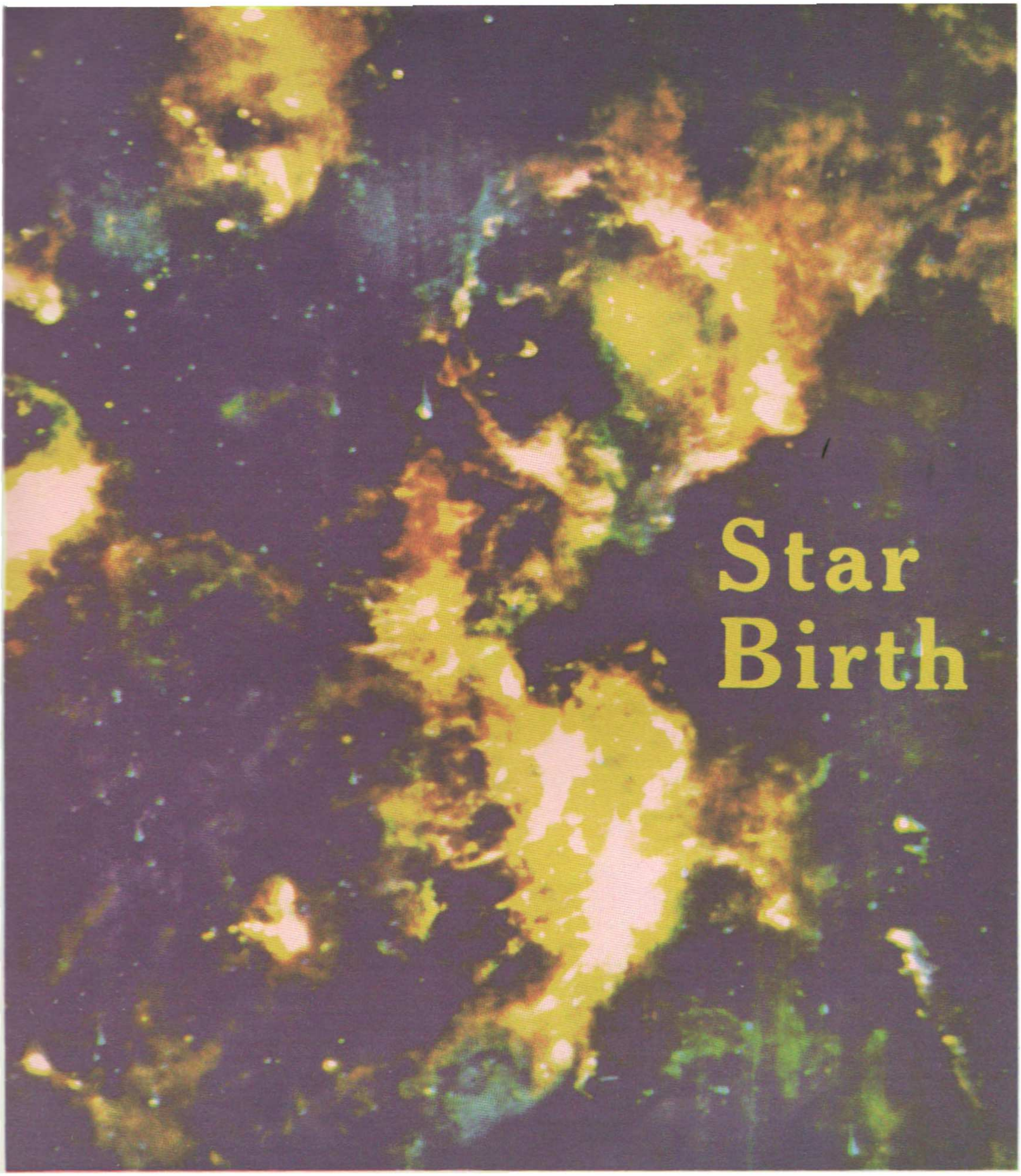
The exploration of space is an adventure that enriches our civilisation and our scientific knowledge. It requires vision to put together a viable programme, the national commitment to provide the necessary resources to carry out the programme, and enabling technology*. The fundamental technology is absolutely essential; without adequate propulsion, guidance, and communication systems Verne and Wells could only chronicle our dreams. But, even today, new technologies must be continually created so that mission planners are not unduly constrained.

On January 21 at JPL a ground-breaking ceremony took place for a new Microdevices Laboratory. This laboratory will represent the physical aspect of the Center for Space Microelectronics Technology, which was formally established the same day by a memorandum of understanding between the California Institute of Technology (JPL's parent organisation) and NASA. The Center will provide long-range supporting research and development in advanced micro-electronics for a wide range of US space-related efforts, particularly for NASA and Department of Defense space missions. Caltech faculty collaboration will be a principal feature of the Center.

The concept for a thrust in microelectronics originated with Dr. Burton Edelson, NASA Associate Administrator for the Office of Space Science and Applications, who requested in July 1983 that JPL establish the Advanced Microelectronics Program (AMP). The director of AMP was Dr. Carl Kukkonen of JPL who now serves as director for the new Center for Space Microelectronics Technology, which will replace and build upon the progress made by AMP. Kukkonen, who holds a doctorate in solid-state physics from Cornell, came to JPL in 1984 from the Ford Motor Company research laboratory. He describes research at the Center as "very much bottom up – in some sense we are planting 100 flowers and seeing which ones flourish". Reflecting the fact that research discoveries can be directed but not mandated, Kukkonen says that his approach is to "hire smart people and expose them to NASA problems".

The obvious motivation for the Center is to develop needed space technologies. But the question arises as to why such technology is not bought from industry. The answer lies in the expected volume of the end products: small. Deep space missions simply do not consume large numbers of parts due to the low frequency of launches, even before the Challenger accident. Thus, the development costs for industry would not be justified by the small profits. Microdevices will be

**Fortunately, the enthusiastic people who supply the motive force for all of this are never in short supply. Witness the foundation of the British Interplanetary Society in Liverpool by a small group of such enthusiasts or the primitive rocket experiments in California's Arroyo Seco that led to the establishment of JPL.*



This false-colour image of the region of sky around the constellation Orion, produced from data from the Infrared Astronomical Satellite (IRAS), shows a different view than that seen from optical telescopes. The field extends about 35 degrees from top to bottom. Intensity of different infrared wavelengths and thus the temperature of the emitting material is represented by colour: red is the coolest material (100 micron wavelength radiation); green is warm material (60 micron wavelength radiation); and blue is material at room temperature or warmer (12 micron wavelength radiation).

Well-known regions of star formation are apparent, such as the Orion Molecular Cloud (large feature dominating lower half of picture), located in and surrounding the sword of Orion. The large ring in the centre of the image is a shell of gas swept up by the expanding gas round a hot young star. The plane of the Milky Way crosses the upper left corner. Extended infrared cirrus clouds associated with the Milky Way are also seen throughout the image.

IRAS was developed by NASA, the Netherlands Agency for Aerospace Programmes, and the United Kingdom's Science and Engineering Research Council. JPL is the US management centre for the project. The image was produced by the Infrared Processing and Analysis Center (IPAC).

The Microdevices Laboratory at JPL will be ready for occupancy in early 1988. NASA/JPL

developed at the Center through proof-of-concept stage and then turned over to private industry to manufacture.

The Microdevices Laboratory, a 38,000 square foot, three-storey structure, will house clean rooms, conventional laboratories, and offices for about 60 people. Occupancy of the $9 million building is expected in early 1988. All work in the Center will be unclassified, and research results will be presented in the appropriate technical literature.

Some highlights of the AMP programme, which will be carried over to the Center for Space Microelectronics Technology, include: fabrication of a detector for submillimeter astronomy; construction and operation of a scanning tunneling microscope, developed at IBM (the investors received the 1986 Nobel Prize in Physics) and capable of magnifying 100 million times; an electronic newal network that imitates some of the characteristics of the human brain; and work on the Hypercube concurrent computer.

Building a Supercomputer

Concurrent processing is a relatively new way of computing. A problem is broken up into several parts and a subcomputer is assigned to each part. The solution results from the total of the concurrent activities of the subcomputers. Sequential processing, the classical approach to computing, addresses the parts of the problem serially. The Center for Space Microelectronics Technology, described above, is developing a concurrent processor which, in its fully implemented version, will serve as a supercomputer.

The version of concurrent processor which the Caltech/JPL team is developing is called a Hypercube and was introduced in the April 1985 edition of this column. The subcomputers, called "nodes" in the case of the Hypercube, must communicate with one another via a set of interconnections: wires today, optical fibers in the future.

For the case of four nodes, the wires lie (in a conceptual sense) along the edges of the square with a node at each vertex. With eight nodes, the cube, a three-dimensional object, serves as the pattern for interconnections with, again, a node at each vertex. Similarly, in a space of n dimensions, the edges of a hypercube supply the conceptual templates for connecting 2^n nodes with wires. Mathematically it can be shown that this scheme implies each node will be connected to n neighbours.

Most computer designers agree that supercomputers must employ some form of concurrent processing in order to continue to increase in capability. Sequential machines are running into constraints imposed by the finite speed of electromagnetic signals. But some basic questions must be addressed. What should the nature of each subcomputer (node) be? How should these elements be interconnected? What programming techniques are most effective? These questions will be addressed in turn.

Generically, three classes of solutions have been proposed for node definition. The first uses a few highly capable nodes, the second employs a moderate number of middle capability nodes and the third goes with a large number of simple nodes. The Cray 2 supercomputer, the current world standard, has an architecture which utilises up to four Cray sequential machines drawing upon a common memory. The second solution is exemplified by the Hypercube, which uses on the order of 100 nodes, each about as powerful as a minicomputer. The third approach, many thousand

simple nodes, is also under development, at Thinking Machines, Inc. in Boston. An advantage of using middle capability nodes is that they can be instantiated with a mass-produced microprocessor chip at each node – a cheap solution. The complex or very simple node configurations require more customising.

The architecture of node interconnection also admits, at least in principle, three graded solutions. One could connect all nodes to a common electrical bus. But the capacity of the bus would be exceeded before many nodes were hung on it. Another extreme is to connect each node directly to every other node. For 100 nodes this requires about 5000 wires; for 1000 nodes the number is close to half a million wires. The computer becomes a block of copper! The Hypercube solution of interconnections is an intermediate architecture and has worked well in practice.

Programming challenges for concurrent processors are posed because most software development, since the start of the computer age, has been oriented to sequential machines. Hence, the Hypercube project has adopted the motto, "A computer is only as good as the work which can be done on it". Twenty-five different applications have been completed and some 40 more are under development. The fields include aerodynamics, artificial intelligence, computer science, applied mathematics, earthquake engineering, geophysics, astrophysics, nuclear physics, and many more.

The efficiency of an application is measured by dividing the speed-up of the calculation (compared with a single node) by the number of nodes. Most applications result in efficiencies in the range of 80 per cent to 100 per cent. The two primary sources of inefficiency are the necessary communications from node to node and a load imbalance between nodes.

Thus, a programmer must decide how to distribute problem assignments amongst the nodes in a way that minimises both load imbalance and the need for internode communications. One method is "task decomposition", wherein each node works on a different aspect of the problem, analogous to Adam Smith's famous "division of labour" in economics. However, this method is limited by the number of subtasks that the original task can be broken into.

A more effective programming approach is termed "data decomposition". Here, each node stores part of the data in its local memory and performs all the tasks on only that subset. For example, an exercise in weather forecasting might assign a selected part of the atmosphere to each node. If enough data can be stored in each node, the computation dominates as a user of machine resources, not internode communications, and the efficiency is high. The truth of this statement rests upon the geometric fact that the ratio of the surface area of a common object to its volume decreases as the object increases in size; the "surfaces" of data structures are just those regions that must be shared – communicated – between nodes. This observation determines the correct amount of memory for each node.

The Hypercube project was started on the Caltech campus in 1981 under the direction of Professors C. Seitz and G. Fox. The resulting Mark I Hypercube (Cosmic Cube) had 64 nodes, each constituted by a 16-bit Intel 8086 microprocessor. This machine demonstrated the performance of about six of the popular VAX-11/780 computers.

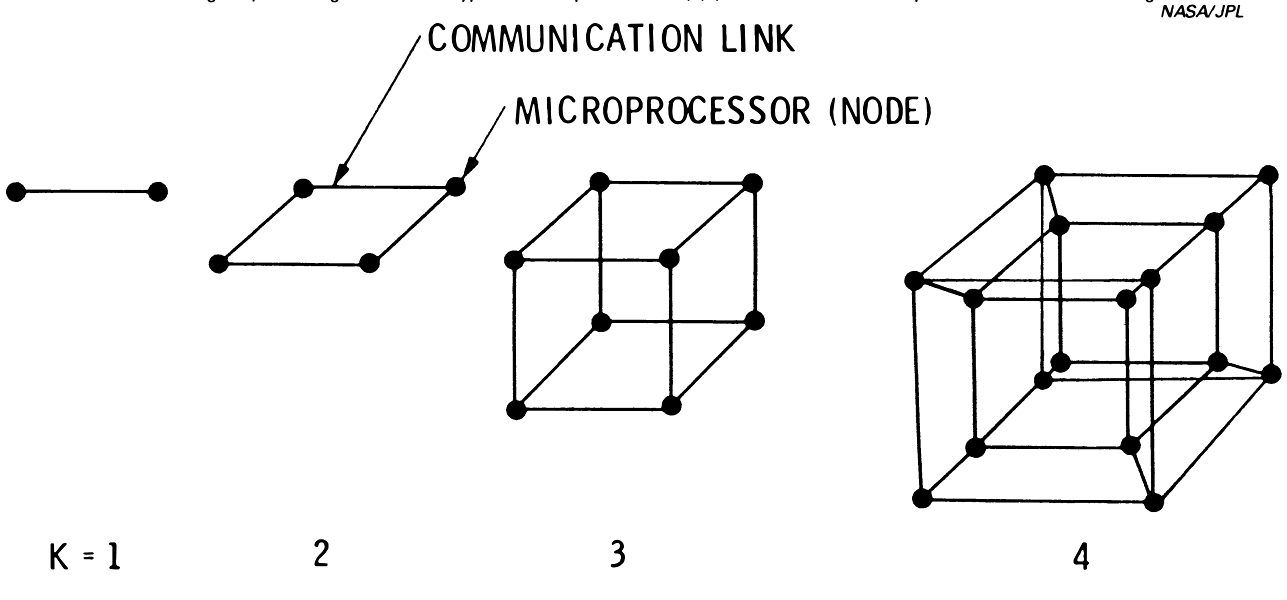
In the fall of 1983, the Caltech Concurrent Computation Project was formally created as a joint endeavour between the Caltech campus and JPL, and a JPL team built the Mark II version of the Hypercube. One 128-node and four 32-node Mark II computers were built. The 128-node system has a performance comparable to about 25 VAX-11/780 machines.

For the last two years, the JPL team has worked on the Mark III Hypercube. This computer utilises a Motorola MC68020 32-bit microprocessor at each node. One Mark III node, by itself, has a performance between one and two VAX-11/780 computers. Two 32-node Mark III machines are now operational. A 128-node Hypercube of this design should be operational in about two years and will serve as the Caltech/JPL supercomputer, with a performance in the range of a Cray 2.

There are now four private companies manufacturing Hypercubes and about 100 such machines are in use around the world, most with 32 nodes.

The ultimate capability of the Hypercube is difficult to forecast, but the goal is to achieve a performance level 100 times that of today's fastest sequential computers.

The scheme for connecting the processing nodes in the Hypercube computer for K=1,2,3, or 4 dimensions is exemplified in this series of drawings.
NASA/JPL



Galileo Spacecraft Changes

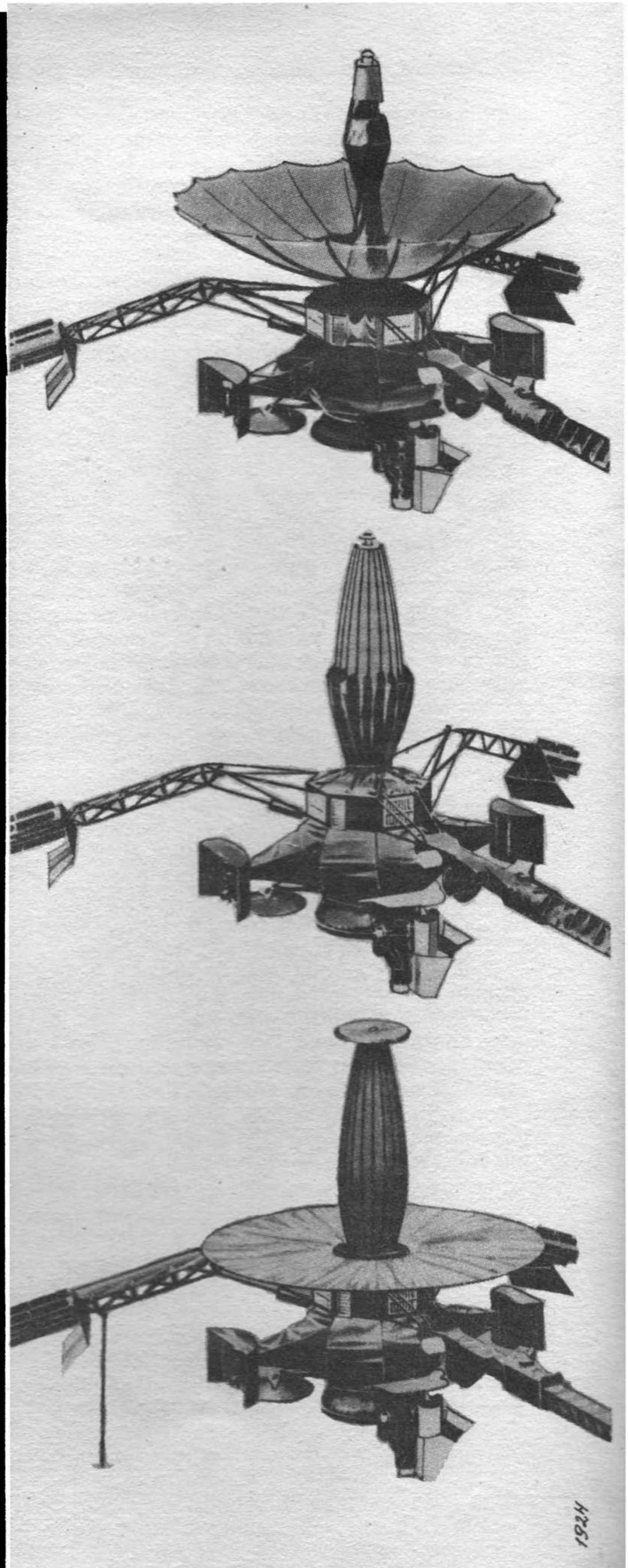
The Galileo spacecraft was very close to launch last year when the Challenger accident occurred in January. The plan for the mission was to launch the spacecraft in May by means of a Shuttle/Centaur G-prime combination and arrive at Jupiter in 1988 to send a probe into the atmosphere and to orbit the giant planet for an extensive programme of scientific investigations.

The Galileo spacecraft had arrived at the Kennedy Space Center (KSC) on December 22, 1985 by truck convoy from Pasadena. Preparations for launch were not terminated with the Challenger accident on January 28. One reason for continuing was that, at first, subsequent Shuttle launches were obviously doubtful but not definitely cancelled. Even after launch cancellation in mid-February, preparation of the Galileo spacecraft was continued in order to gain valuable interface experience with the Shuttle and Centaur G-prime (neither had ever been used for a planetary launch). The plan was to establish a near-flight configuration for the spacecraft and Centaur G-prime on the launch pad with the Shuttle Atlantis, the specially fitted vehicle designated for the Galileo launch, and then store the spacecraft at KSC until the time arrived to reconfigure and launch.

Richard Spehalski, the Flight Systems Integration Manager for Project Galileo, described some of the launch-related activities in 1986; he spent the period from January to July at KSC. The Galileo spacecraft was placed in a bay in the Vertical Processing Facility in full-flight configuration, including tanks filled with fuel. Then it was lifted atop the Centaur G-prime and an interface was established with the Centaur stage and with simulated Shuttle electronic systems in the payload processing bay. The next step was to have been enclosure of the spacecraft and the upper stage in a canister prior to transfer from the Vertical Processing Facility to the launch pad for continuance of checkout. The whole procedure would have been completed in July (a slower test schedule was established than the original one leading to the May launch). But with cancellation in June of the Centaur G-prime as a Shuttle upper stage, the checkout procedure stopped just short of enclosure in the canister.

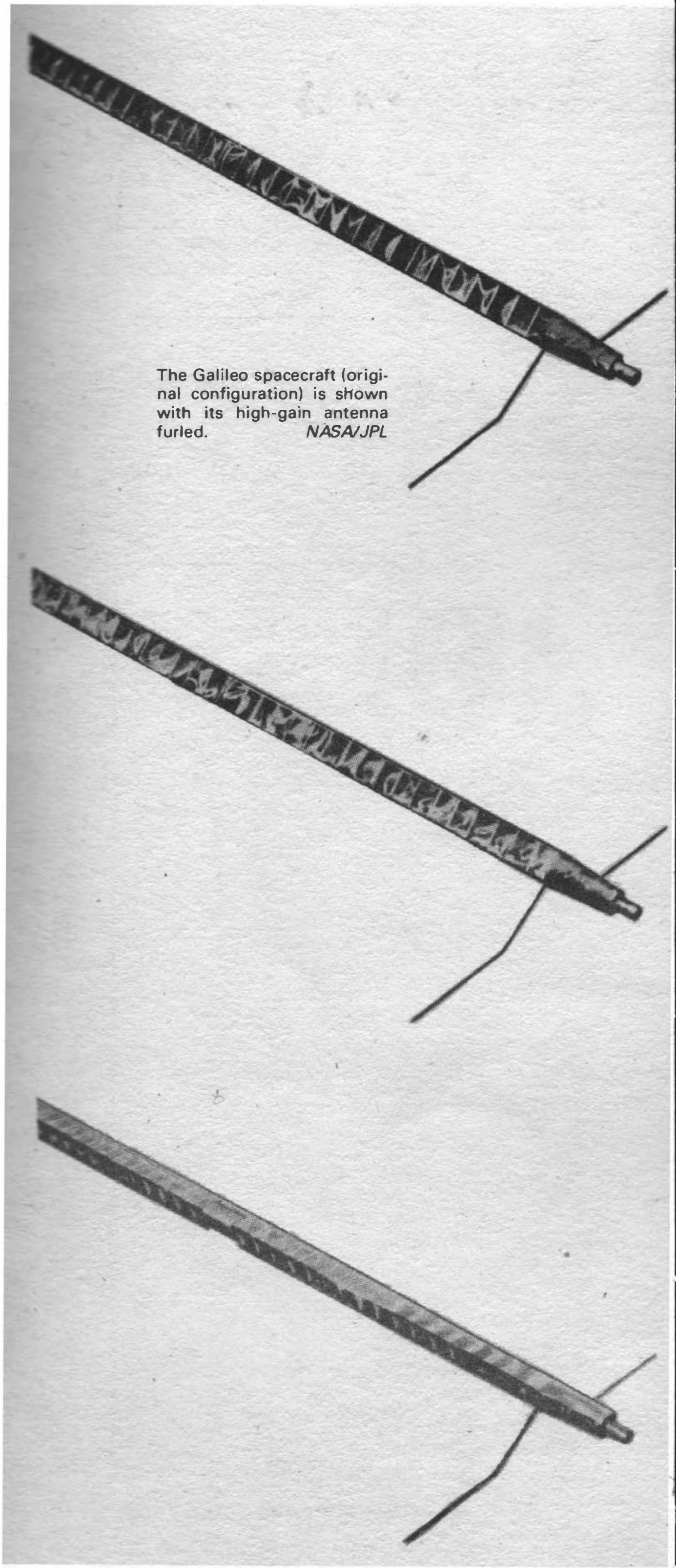
Spehalski said that it was then still planned to store the spacecraft at the Cape with a few project personnel remaining to monitor health and environmental control. But, with the discovery and adoption of the mission option that included a gravity assist from Venus on the way to Jupiter, it was necessary to return the spacecraft to JPL for adaptation to the warmer environment at Venusian distance from the Sun. This new requirement necessitated extensive changes to the thermal design of the spacecraft. The need to prove the new design by testing in a space simulator forced the decision to return the spacecraft to JPL.

The project plan calls for launch in October 1989 by means of a Shuttle/IUS combination with one gravity assist from Venus and two from Earth, prior to proceeding to Jupiter, in order to compensate for the loss of the powerful Centaur G-prime. Arrival at Jupiter is, consequently, delayed until late 1995. See the November 1986 "Space at JPL" for a descrip-



In this drawing, the Galileo spacecraft is shown in the configuration it will employ while close to the Sun; the furled high-gain antenna will be pointed toward the Sun. Compare with the original configuration and note the Sun shades on the tip of the high-gain antenna and skirting its base. The longer boom has been rotated so that its flat side faces the Sun, and a new low-gain antenna is evident on the shorter boom, to allow communications with Earth during the time that the high-gain antenna is Sun pointed. *NASA/JPL*

The Galileo spacecraft is shown in this drawing by Ken Hodges as it was configured for flight after the May 1986 launch, cancelled as a result of the Challenger accident. ***NASA/JPL***



The Galileo spacecraft (original configuration) is shown with its high-gain antenna furled. *NASA/JPL*

tion of the flight path, which is often referred to as the "cruiser" mission due to the significant amount of time spent in interplanetary cruise.

Travel can be a traumatic event for humans. It definitely poses problems for a spacecraft: security, environmental control, communications, and road hazards. The transfer vehicle contains temperature and humidity controls and monitoring devices that are displayed in the driver's cab. The environmental control system has several back-up diesel generators to prevent power failure. Dynamic alarms warn against rough roads and insure that a part could not come loose during the trip without the immediate knowledge of the driver.

The convoy arrived at JPL on February 21. Three tasks faced the spacecraft engineers: (1) provide and test modifications necessary for the new mission, (2) fix a few problems that had arisen on the spacecraft, and (3) examine all subsystems and instruments to insure that they are qualified for the longer lifetime required for the cruiser mission. The first priority was to begin the thermal redesign. Thermal control is provided by heaters placed at strategic locations, by thermostatically controlled louvres, and by thermal blankets wrapped on the exterior of the spacecraft. In addition, Galileo needed to add sunshades to its thermal armamentarium.

Thermal blankets were originally present on the spacecraft but had to be redesigned for the new environmental conditions. Fitting thermal blankets to a spacecraft is somewhat like fitting a suit to a human, according to Spehalski. After visual inspection, and bearing in mind the design requirement of maintaining the same internal spacecraft temperatures as for the original mission, paper and masking tape were used to define the shape of the outer surface of the spacecraft: "patterning" for the new thermal blankets. This activity is currently underway. The next step is to cut the thermal blanket materials with the aid of these patterns or hardboard templates. Blankets are composed of many layers of various thin materials, such as aluminised mylar, which act as radiation shields to reduce heat transfer through the blanket. After cutting, the layers are stitched together to yield the blanket.

When the Galileo spacecraft is inside the Earth's orbit, it will have its high-gain antenna closed into a pod-like shape and pointed toward the Sun. A small shade at the tip of the antenna will protect it from the Sun, and a larger shade will fit as a skirt around the base of the antenna in order to shield the main body of the spacecraft from the Sun's rays. A few smaller shades will be placed at selected locations.

The spacecraft's long magnetic boom is wrapped in an electrically conducting blanket to protect against electrostatic discharge. For the cruiser mission this structure, which has a triangular cross section, will be re-wrapped and rotated 180 degrees from its original position to present a flat side to the Sun. This orientation minimises solar reflections into the optics of sensitive instruments and also provides a more thermally satisfactory environment for the boom.

With the spacecraft's high-gain and low-gain antennae pointed toward the Sun during a portion of the mission, it is necessary to add another low-gain antenna to the vehicle, on the aft hemisphere, in order to maintain communications with Earth. Before the final leg to Jupiter, the cruiser mission will yield incursions into the asteroid belt. At these times, the space-craft being outside the orbit of Earth, the high-gain antenna can be unfurled during passage by an asteroid in order to allow the return of the requisite amount of scientific information.

Several other hardware modifications are planned and new flight software is being produced for the onboard computer.

Following the changes, the spacecraft will be tested in the solar-thermal-vacuum chamber at JPL in July and August of 1988. It will be shipped back to KSC in mid-May of 1989, its long residence on Earth nearly at an end.

JUNE 1987 $3.00 £1.25

Spaceflight

The International Magazine of Space and Astronautics

FUTURE SPACEPLANES

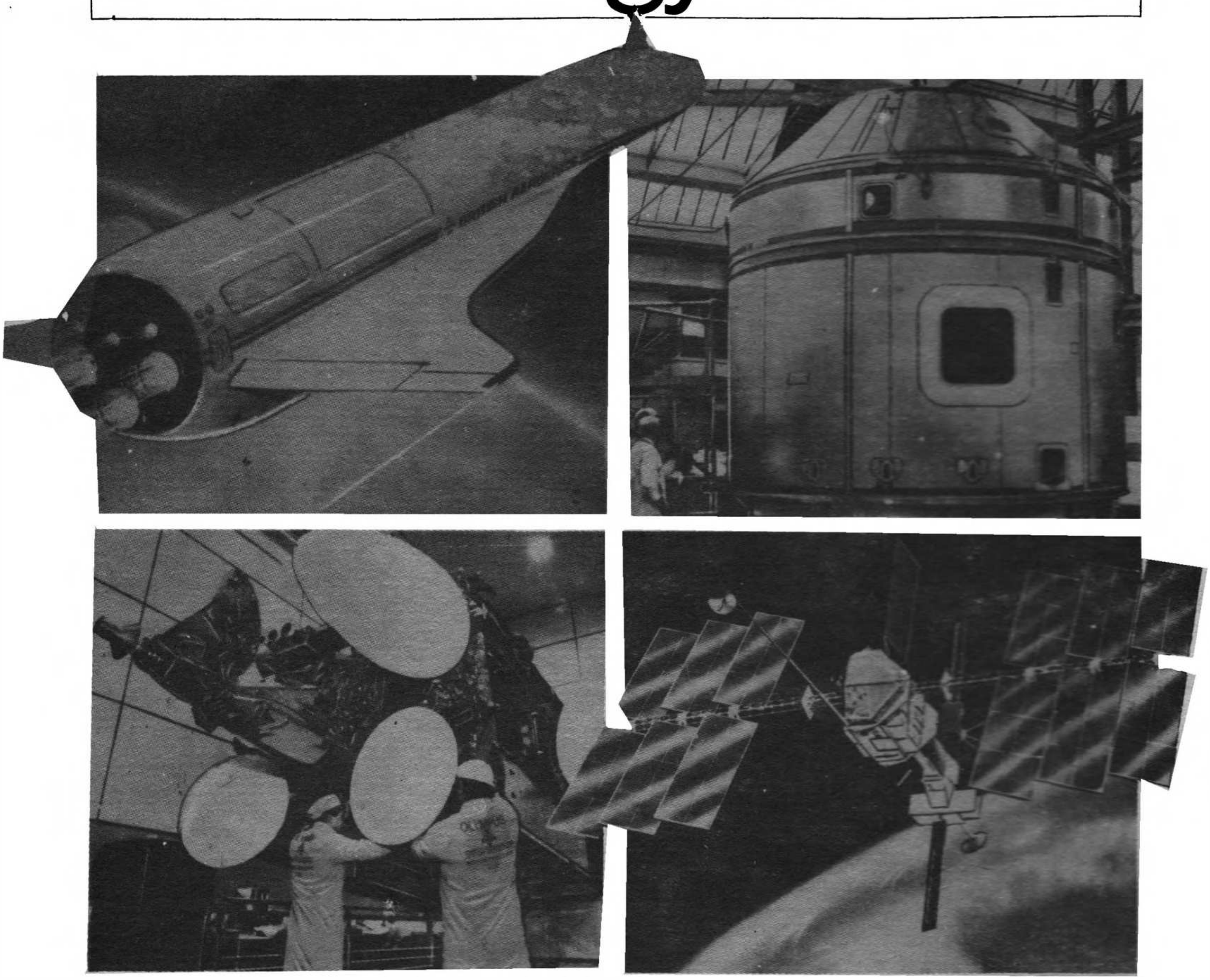
Man in Space
NASA'S LONG-TERM ROLE

Soviet Dockings
MANNED OPERATIONS AT MIR

SPACE NEWS and REPORTS

Vol. 29
Nos. 6/7

Making Space Technology Work...



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Spaceflight may be received worldwide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH, England. Tel. 0344 884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Published monthly by the **British Interplanetary Society Ltd.,** 27/29 South Lambeth Road, London, SW8 1SZ, England. *United States:* Subscription $33.00, second class postage paid at New York NY. Postmaster: send address corrections to ***Spaceflight***, c/o Expediters of the Printed Word Ltd., 515 Madison Avenue, New York NY 10022.

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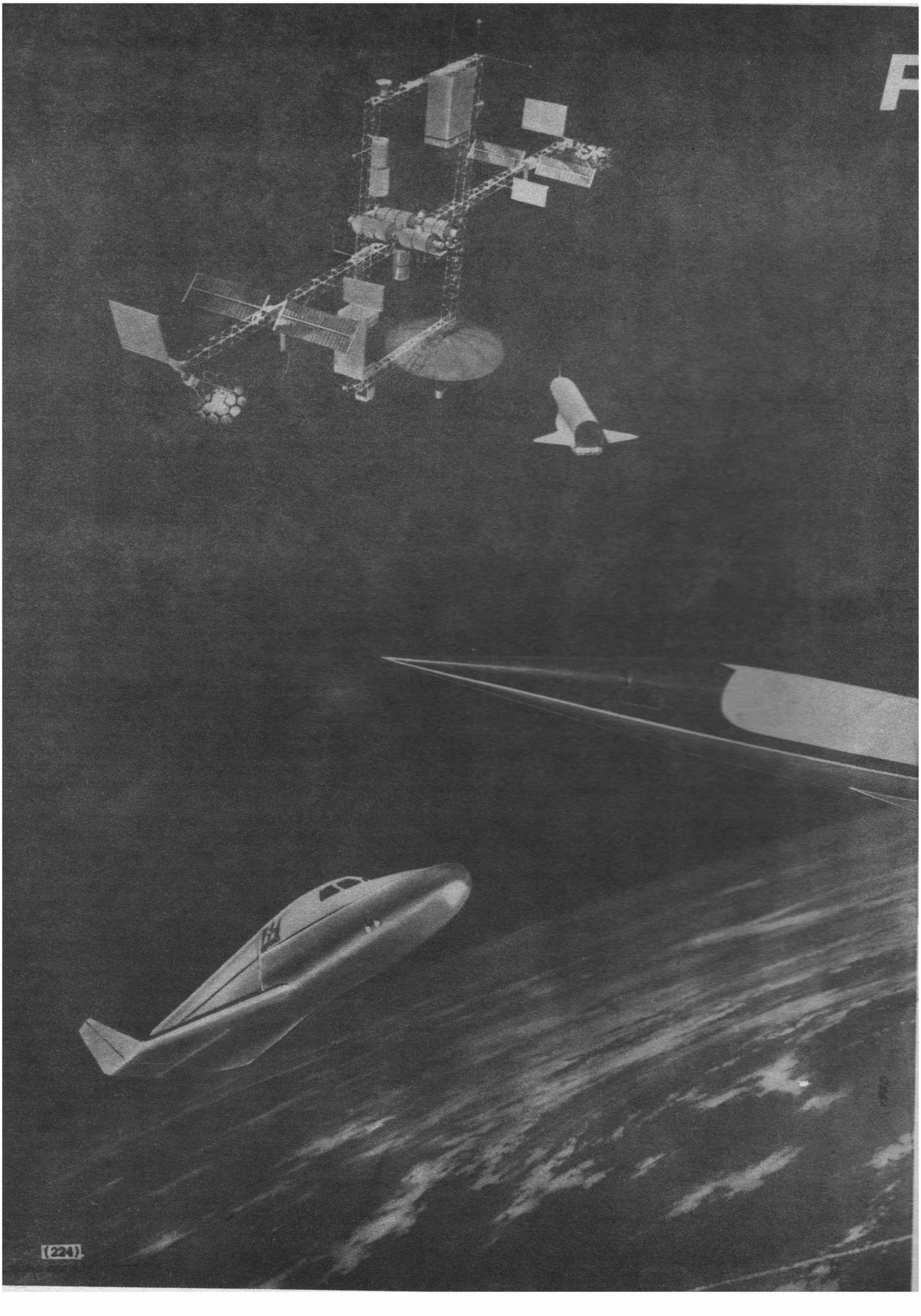
Spaceflight

The International Magazine of Space and Astronautics

Vol. 29 Nos. 6/7 June 1987

Front Cover: An artist's concept of a US aerospaceplane showing aero-thermal heating effects cause by friction as the vehicle flies hypersonically through the atmosphere (see 'Future Spaceplanes', p.224). *Leslie Bossinas/NASA*

Back Cover: Soyuz 19 viewed from Apollo during the Apollo/Soyuz Test Project in 1975 which is the only joint US/Soviet space mission to have taken place.



uture Spaceplanes

The Hermes spaceplane (lower left) is an ESA project at the stage of technological assessment prior to development. Like the US Shuttle it is intended to be launched vertically by conventional rocketry – in this case the Ariane 5.

Only spaceplanes that climb to orbit, aircraft-like, from a horizontal take-off are likely to offer the lower costs and operational success needed for developing space in the 21st century. The proposed US aero-spaceplane is pictured here in its climb to an orbital space station and the Hotol vehicle is seen in the distance.

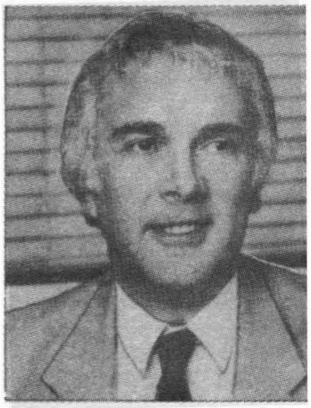
In this issue, *Spaceflight* provides a special report on the current status of spaceplanes based on information presented at the British Interplanetary Society's international symposium "Future Spaceplanes" held in London on April 29, 1987. Attendees numbered over 100 and included representatives from UK, France, Germany, Japan, the USA and the USSR.

Future Spaceplanes

The UK may look for alternative means of funding Hotol studies and its future development if the European Space Agency does not agree at a ministerial meeting in the autumn to embrace the project.

Speaking at the British Interplanetary Society's "Future Spaceplanes" Symposium in London, Mr. Jack Leeming, BNSC, Director of Policy and Programmes, said the meeting of European Ministers was now scheduled for October or November instead of the early summer.

"We don't take the view that this country can afford Hotol on its own so we have proposed that it be 'Europeanised' within the FESTIP (Future European Space Technology Infrastructure Programme)," he told the delegates.



Mr. Jack Leeming.

"I hope it is agreed at the ministerial meeting later this year that a three to four year programme to analyse relevant technologies and funded at adequate levels is started within ESA. "We are at a stage where no country has a right to lay out the future of space transportation and studies should be carried forward in an integrated way."

But he warned: "If not, we will have to examine the possibility of funding it domestically in the way the French and Germans do when a project is not accepted fully by ESA."

Earlier, in his opening address to the Conference, Mr Leeming said it was very easy to be pessimistic about future launchers in view of the failures in the West during the last 12 months.

"I must congratulate the British Interplanetary Society for its foresight in looking beyond our immediate problems. Today we are looking into the next century", he stated.

Mr. Leeming said the way forward was for a safer and more routine basis of getting into space coupled with a dramatic lowering in cost.

"Only if we achieve both of these together are we really likely to open up near Earth orbit in the next century for commercialisation and scientific purposes.

"Another lesson of the past is that depending on one system is a rather hazardous business – a single launcher or a single country for launcher design is something we should think carefully about.

"We should collectively look to see what the requirements for launchers are, what the competition will be and what the need is for ESA if we are to maintain autonomy in this field," he added.

Depending on one system is a rather hazardous business.

Mr. Leeming concluded that Europe should be ready to make a decision in the early part of the next decade as to what kind of launcher it should develop to start operations in the 2005 and 2010 period.

Hotol

The importance of Hotol was explained by Mr. G.P. Wilson of British Aerospace (Warton) in terms of the expected doubling every 10-15 years of the present 200 t per annum of payload placed in orbit. Space Shuttle launchings at 12 per year will carry 250 t per annum to orbit and expendable vehicles can be expected to carry a further 200 t per annum, so by the end of the century more launch capacity will be needed.

Current launchers have serious disadvantages. They are inflexible with 'choke points' in the ground assembly such that one hold-up can delay the whole fleet. Also they are too expensive, expendable vehicles being completely lost and the Shuttle, although reusable, requiring some 5000 ground personnel.

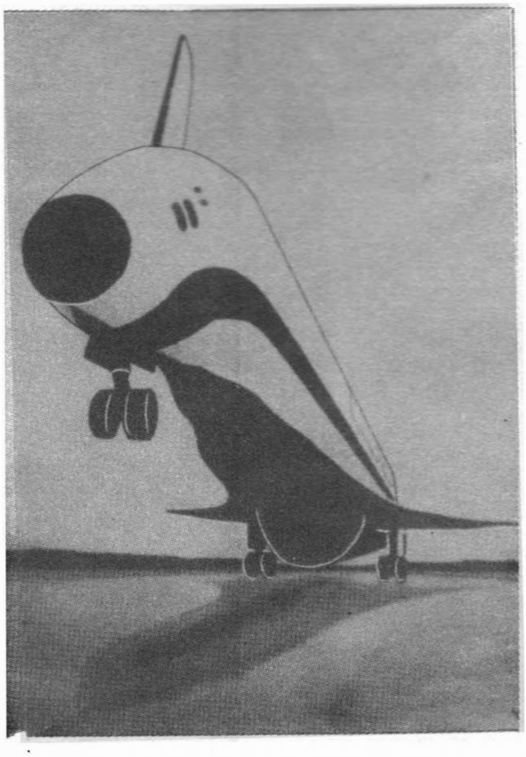
Future needs are for a cost-effective means of transport with aircraft-like operating capability and a single payload design to avoid the delays that arise with multiple payloads. Hotol meets these requirements.

Compared with the Space Shuttle, Hotol has the same body diameter and twice the length being comparable with that of the Shuttle's external tank. Its thrust-to-weight is 0.6 compared with 1.5 for the Shuttle.

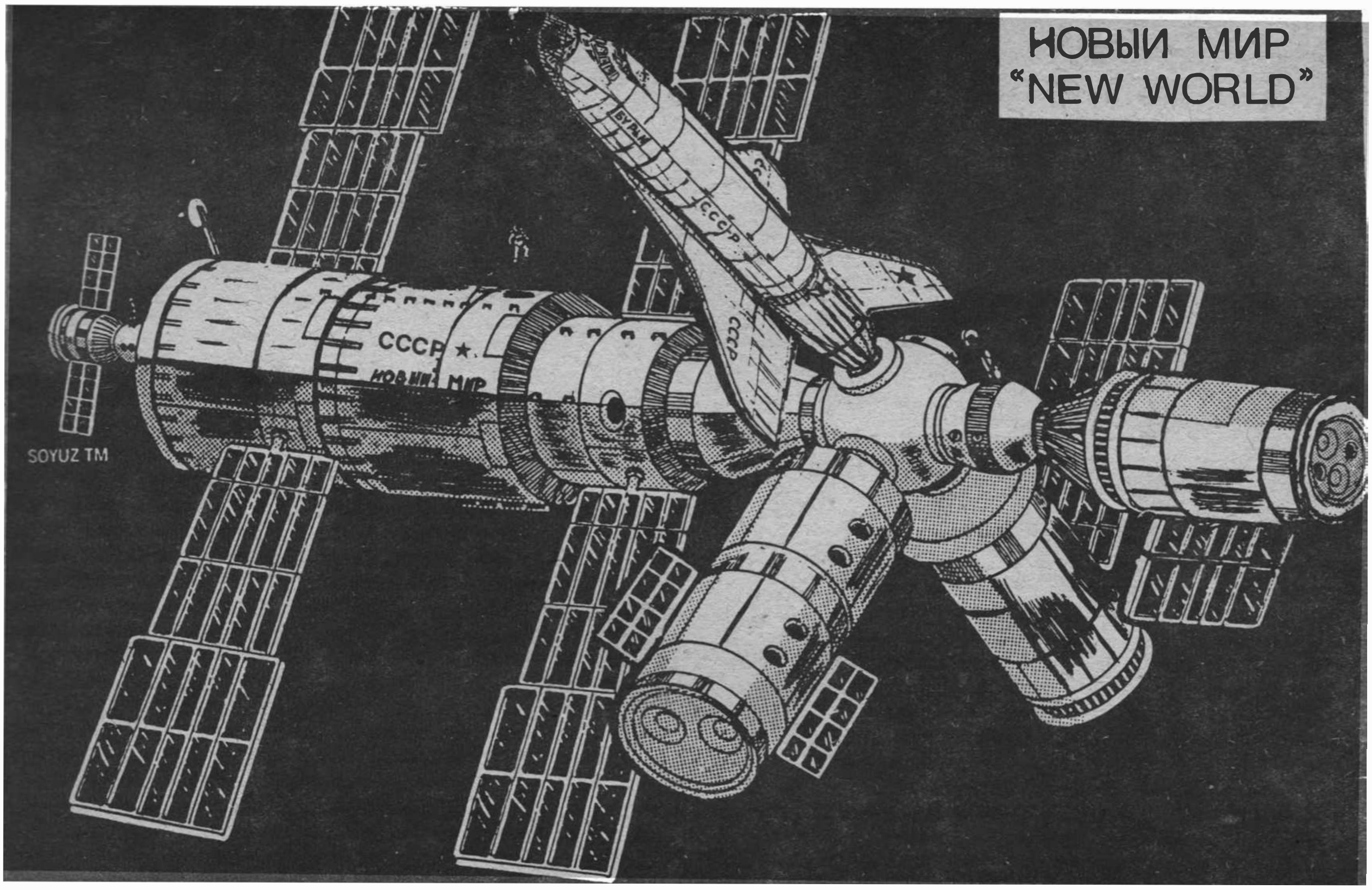
At the present time, work on the 'Proof-of-Concept' studies which are being jointly sponsored by BNSC and Industry (British Aerospace and Rolls Royce) is well underway.

Tests on engineering models of

The essence of a spaceplane is to provide a cost-effective and safe means of transporting men and hardware into low-Earth orbit. Only if these objectives can be achieved will the way be opened for the future commercialisation and exploitation of near-Earth space.



Hotol makes a runway landing after a routine mission to orbit in this impression by space artist ***Ian Moule***.



The illustration above shows a possible scenario for future Soviet manned operations in near-Earth orbit. The basic block consists of a Mk II Mir Space Station, larger than the current Mir, with various modules and extensions attached to the docking ports. Also depicted docked to a lateral port is a Soviet Shuttle craft. In his paper "The Soviet Space Shuttle Programme" Mr. Tony Lawton said the Shuttle had undergone six firings to date and was "almost ready to go". He surmised that the first flight would be entirely automatic.

Hotol have now been carried out by British Aerospace in four wind tunnels up to Mach 5.5 including the 4.0 ft supersonic tunnel at Warton, where a 1/76 th scale model has been tested to Mach 3. Independent tests are also being conducted on wind tunnel models at Southampton University up to Mach 8.7.

Hermes

Following the Challenger accident a reappraisal of Hermes safety requirements has been undertaken leading to a redesigned configuration with an ejectable crew cabin of increased volumn and mass. It would be effective from lift-off with crew acceleration not exceeding 7g. To increase abort safety, an additional propulsion stage has been included in the conical adapter connecting Hermes to the Ariane 5 launcher.

In describing these changes, M. Cretenet of CNES explained that trade-off studies were now in progress to enable the original performance objective of placing a 21 t Hermes in a 500 km orbit to be achieved and to dock with the Mir or other space stations. The Hermes docking interface is in the tail.

The effect of the design changes on the forthcoming development programme for Hermes is difficult to say at the present time, said M. Cretenet, but the 1995 launch date may be delayed by one or two years.

HOPE

Details of Japanese efforts in the spaceplane arena were given by Mr. Toshio Akimoto, of the National Space Development Agency of Japan (NASDA), in a paper entitled "Conceptual Studies on the H-II orbiting Plane".

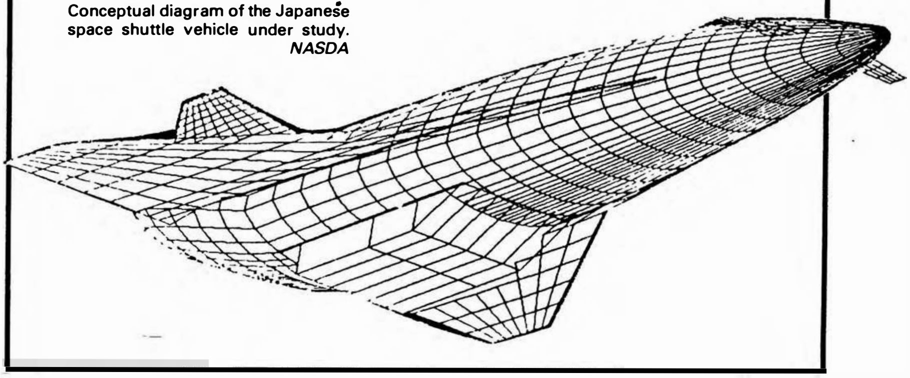
As implied in the title, the Japanese spaceplane, HOPE (for H-II Orbiting Plane), is planned for launch atop the H-II booster in a similar fashion to Europe's proposed Ariane V/Hermes configuration.

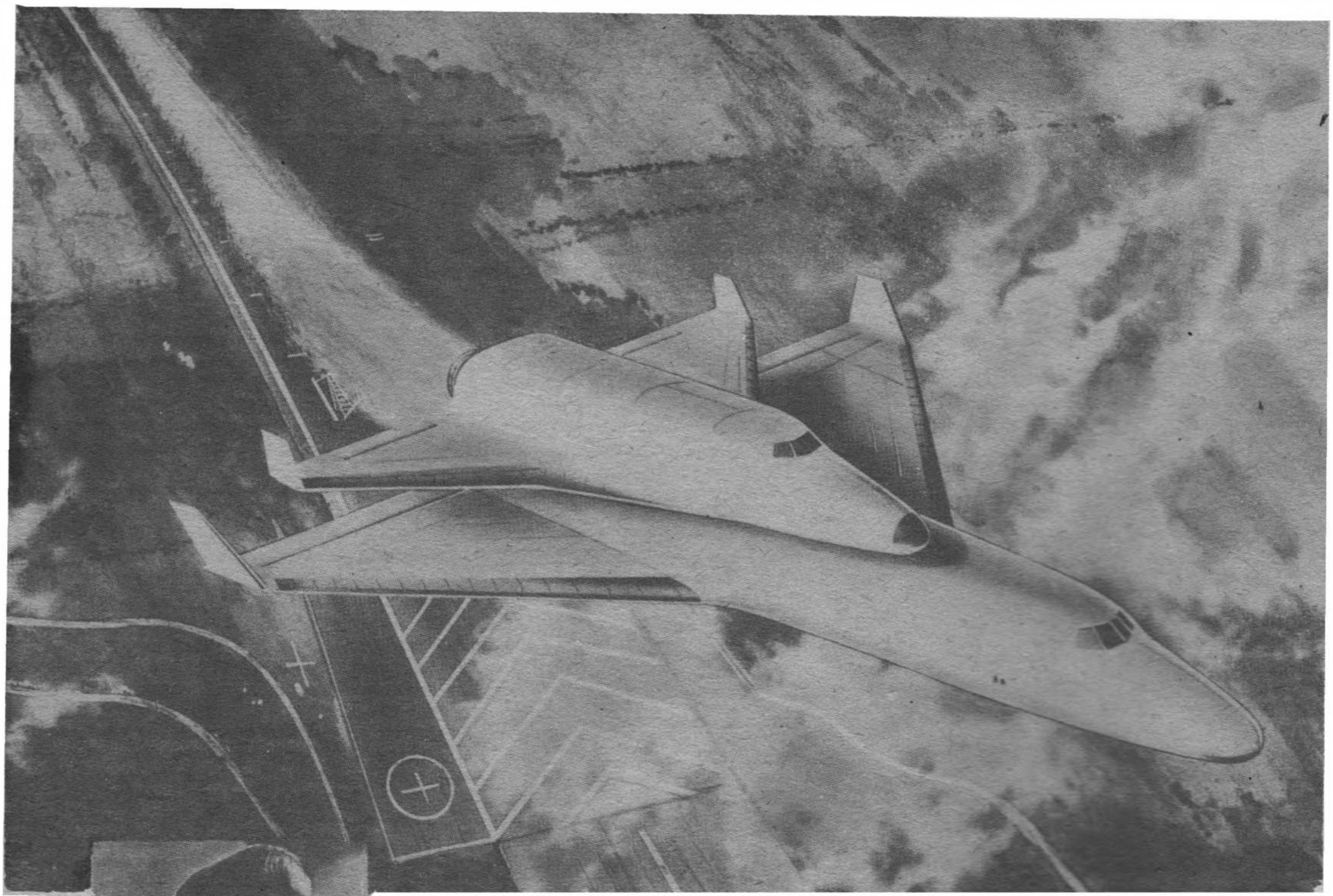
Mr. Akimoto outlined the conceptual studies being undertaken in Japan for a vehicle which would undergo its first flight test in 1995.

He said the studies had involved the consideration of five variants:

- A 10 ton unmanned spaceplane (U1) capable of lifting a three ton payload.
- A 10 ton manned spaceplane (M1) capable of orbiting a crews of two and a one ton payload.
- A 20 ton manned spaceplane (M2) capable of carrying four crew and four tons of payload.
- A 29 ton manned spaceplane (M4) with a crew of two and a one ton payload, plus internal propulsion.
- A 10 ton manned spaceplane (M1J) with a jet engine two crew members and a one ton payload.

Conceptual diagram of the Japanese space shuttle vehicle under study.
NASDA





Artist's concept of a launch from a standard runway of the German Sanger/Horus spaceplane. *MBB*

Eugen Sanger 1905-64.

Under the development schedule discussed by Mr. Akimoto phase B design studies will be completed by 1990 with phase C and D development taking place between 1990 and 1995.

X-30 National Aero-Spaceplane

The United States' $3.3 billion programme to build a national aerospaceplane will take further steps forward this summer.

This month (June) will see the start of an engine concept review and in August two of the three companies involved – General Electric, Pratt and Whitney and Rocketdyne – will be selected to continue the project's concept validation phase.

In October, after a two month review, three contractors will be selected to develop demonstration hardware for the hypersonic airframe. Those currently involved in these studies are: Boeing, General Dynamics, Lockheed, McDonnel Douglas and Rockwell International.

The X-30 project, being funded jointly by the US Department of Defense (80 per cent) and NASA (20 per cent), will have both military and civil applications. User studies are currently concentrating on three areas: reconnaisance missions, a manned, single-stage-to-orbit vehicle and a hypersonic transport known in popular terms as "the Orient Express".

The fiscal 1988 budget request for the X-30 project totals $320 million, with a further $411 million planned for 1989 and significant increases in ensuing years leading up to construction of two flight vehicles.

If the programme proceeds according to plan, selection of main contractors for the airframe and scramjet engines is expected in 1989.

Sanger

In his paper "The Two Stage Sanger Space Transport System", Dr. H. Kuczena, of the German aerospace firm MBB, said Sanger would combine two development lines – an aircraft concept, such as Concorde, and the Shuttle concept as exemplified by the US Shuttle and Hermes.

He explained that the upper stage of the vehicle, Horus, a derivative of Hermes, would be used in conjunction with a hypersonic transport plane, Sanger. As a global transport, Sanger would be able to carry 130 passengers a distance of 13,000 km. Among propulsion systems being considered are combinations of turbo and ramjet engines for the first stage Sanger vehicle.

There are also plans for an expendable upper stage version for carrying payloads of up to 15 tons into low-Earth orbit. 1970

Horus of 91,000 kg weight would be for manned missions only and would carry a crew of two. Uses of Horus would include servicing the space station, missions to polar orbit and reconnaissance work.

Dr. Kuczena said thinking behind the idea was to develop a system capable of being launched in Europe with the ability to cruise to an equatorial latitude for a more favourable launch location.

Horus, as a derivative of Hermes, would benefit from lessons learnt in the French-led programme. Launch costs would be 10 to 15 per cent that of Hermes with a two to four ton payload capability.

Cargus, the unmanned version, is estimated as being able to carry the same payload into orbit as an Ariane V but at approximately one third of the cost.

Development is expected to start in 1994 and operations started in 2005, after which launches should complement those of the US Vehicle.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Shuttle Testing Impacts Launch Date

Plans to resume US Space Shuttle flights by February 18 next year have been abandoned by NASA.

Former astronaut Admiral Richard H. Truly, NASA Associate Administrator for Space Flight, announced in April that a final decision to perform two major systems tests prior to the next Space Shuttle launch will result in a new target launch date.

A "wet" countdown demonstration test, in which the external tank is filled with fuel for a simulated launch countdown, and a flight readiness firing, in which the main engines are fired for about 20 seconds, will be performed on a Shuttle orbiter Discovery at the Kennedy Space Center, prior to launch.

These tests will provide the needed engineering data to evaluate and confirm various systems modifications, as well as exercise the launch and mission control teams after the hiatus in Space Shuttle operations.

NASA states that "several weeks" will be added to the overall processing time for Discovery, which will be used for the flight, but other estimates have put the launch back to the second half of the year at the earliest.

In addition there is an ongoing assessment of the status of other programme elements – such as the redesigned solid rocket motor, the Space Shuttle main engines, and the processing time required to implement orbiter modifications – and their potential impact on the flight schedule.

NASA engineer Stokes McMillan during an eight hour Joint Integrated Simulation of Inertial Upper Stage/ TDRS deployments. The April 14 simulation was one of several precursors to the long-duration simulation at the end of the month. A TDRS satellite will be launched by STS-26.

A shift in the launch of Discovery for mission STS-26 to the latter part of 1988 will mean slipping the remaining launches scheduled for the year into 1989 (see 'Shuttle Launch Manifest', *Space-flight*, Nov 1986, p.378).

NASA is expected to announce a new schedule in the early summer following assessment of the various factors involved.

Planetary Missions Set For '89 and '90

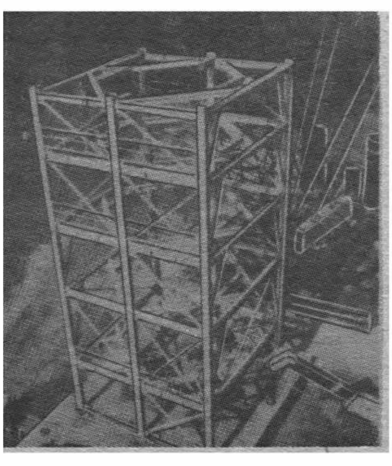
NASA Administrator James Fletcher and ESA Director General Reimar Lüst announced on April 3 the decision to launch the joint NASA/ESA Ulysses mission to the Sun in October 1990 using the Space Shuttle. The Galileo mission to Jupiter will be launched in October 1989, also from a Shuttle, *writes Dr. W.I. McLaughlin.*

The decision on the launch sequence was principally based on a desire to optimise the data return from these two missions. Even though Ulysses will be launched a year later than Galileo, it will begin to return prime data in 1994, one year earlier than the Galileo spacecraft.

Attempting to launch both spacecraft during the "Jupiter window" (Ulysses employs a gravity assist from Jupiter to fling it out of the ecliptic and above the solar poles) would have resulted in unacceptable schedule and launch risks.

Tower for SRM Qualification

Construction work is continuing on the access tower for the Transient Pressure Test Article (TPTA) at the Marshall Space Flight Center – a 75 foot tower for solid rocket motor (SRM) short-duration ignition pressure tests.



Behind the tower (pictured left) is a ringer crane which will be used for handling and stacking test hardware.

The objective of the TPTA testing is to verify the new solid rocket motor field and nozzle joints and testing is scheduled to begin at Marshall in September 1987.

The series of pressure tests, in conjunction with tests being conducted at Morton Thiokol (Joint Environment Simulator tests) and full-scale motor firings, are expected to lead to qualification of the improved solid rocket motor joint re-design near the end of this year.

Picture NASA

INTERNATIONAL SPACE REPORT

Australia Analyses Space Potential

Australia's ambitious plans for a 21st Century international spaceport were revealed briefly in last month's *Spaceflight* (p.183). In this issue we assess the proposal in more detail beginning with an introduction by John Sved, followed by comments from Sir Joh Bjelke-Petersen, the Premier and Treasurer of Queensland, and an overview of the initial study based on the *Cape York International Spaceport* Report executive summary.

The Cape York International Spaceport Feasibility Study Part 1 report is prefaced with a declaration of its dual rôle as a source of advice to politicians, public servants, industrialists and the general public plus experienced space authorities and commercial launch vehicle developers outside Australia. Both categories are well served so that confidence can be established to support more detailed studies, ***writes John Sved.***

The report concludes that a spaceport complex occupying initially 2000 sq. km near the bauxite mining operation at Weipa, lying on the west coast, can provide access to both low inclination and polar sun-synchronous orbits. The Phase 1 development would support expendable launch vehicles with phase 2 providing expansion of the spaceport for reusable launcher systems and payload preparation geared to expected traffic in 10 to 15 years. The report surveys launcher systems that have recently been in the technical press and summarises market growth forecasts.

Two regions were considered, with latitudes of 11 and 12 degrees south. The region more distant from the equator has been advocated due to an established transportation and communications infrastructure and favourable weather patterns.

In the south Pacific region populated islands do not lie in the drop zones for spent stages of the ELVs presently operational; nor are proposed two stage commercial ELVs likley to pose a hazard for easterly flights and polar launchings would overfly very sparsely populated central Australia. Entry into the airspace of neighbouring countries could be avoided during the sub-orbital launch flight phase or during the return to base flight of a reusable orbiter. Other potential equatorial launch sites are compared and none are able to include all of the assets which the Cape York site appears to possess.

The report contains ample graphical material to support the analysis. Meteorological, seismicity, radar and downrange tracking as well as the preliminary trajectory and drop zone analysis are displayed in charts. However, it is not the first such study. *Launching Site for Equatorial Orbits for ELDO* was a study prepared by the department of Supply in 1965 which advocated a site near Darwin. ELDO moved to French Guiana and Woomera was effectively closed.

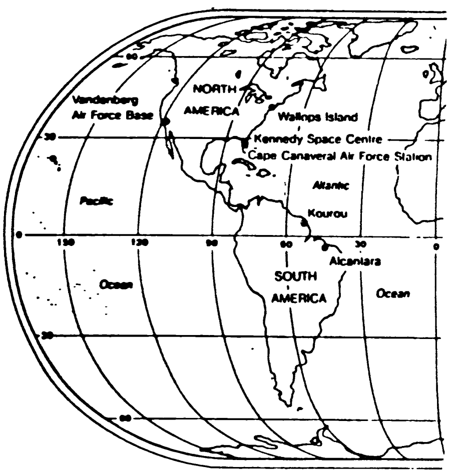


Figure 1: Geographical location of launch sites [●] and proposed sites [⊥] around the world.

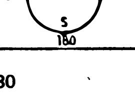
The spaceport is expected to have the status of a "Free Trade Zone" although legal and trade aspects were not examined in detail by the engineering based steering committee – this will be done in next study phase.

The extent of peripheral industrial and economic activity was indicated only indirectly through market size forecasts and estimates of land area (up to 10000 sq. km). While propellant requirements were surveyed, the report did not indicate the feasibility of local production of hypergolics and cryogenics and their usage rates. There was no consideration of the attraction of manufacturing flight hardware in Australia where production costs would be competitive with those for a United States made ELV of totally new design. Such package deals may be seen later when specific proposals are made.

The Queensland Government is now soliciting preliminary contact from interested commercial consortia and the Australian Commonwealth Government will also be involved due to its legislative function.

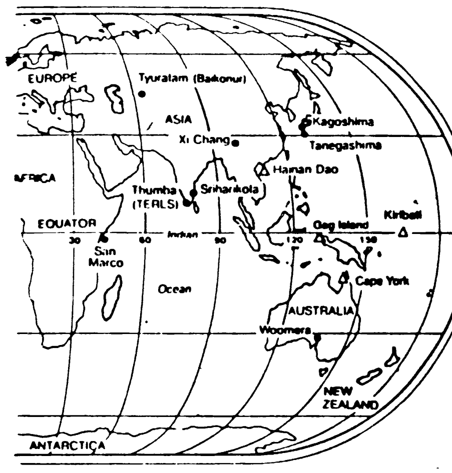
A minimal Space Board has been established but it has still to recommend a coordinated policy and the emergence of a national Space Policy is yet to be seen. A state government has taken the initiative to create a sustained industrial operation in the space business.

Tabel 1: Comparison of launch sites.

SITE / PARAMETER	CAPE YORK SPACE PORT	KENNEDY SPACE CENTER	KOUROU	TANEGASHIMA	BAIKONUR	XI-CHANG
Location	12°15'S 142°E Approx.	28°37'N 80°41'W	5°08'N 52°37'W	30°22'N 130°57'E	46°N 63°E	28°N 102°E
Country	Australia	U.S.A.	French	Japan	U.S.S.R.	China
Available Site Area km^2	Up to 10 000	3 460	1 000	8.65	Unknown	Unknown
Annual Rainfall mm	1923	1148	3238	Unknown (Medium)	Unknown (Low)	Unknown (Low)
Average Thunder-storm Days/Year	39	76	81	Unknown	Unknown	Unknown
Average Fog Days/Year	3	54-vis.11km 11-vis. 1km	Unknown	Unknown (Thought Significant)	Unknown	Unknown
Average Temperature °C	26.9	21.7	26.6	Approx. 17	Approx. 13	Approx. 15
Lowest Minimum Temperature °C	15	-4	18.3	Approx. -5	Approx. -40	Approx. -30
Equatorial Velocity Penalty %	5.3	24.7	0.9	27.1	55	24
Launch Directions Possible - degrees  360 0 N 270 W E 90 S 180	90 to 144* and 192 to 220** *Over Water **Over Water Then Land	35 to 120 Over Water	350 to 93.5 Over Water	60 to 165 Approx. Over Water	0 to 120 Approx. Nearest township 50 km at 90° Large Population 325 km at 190° Large Population 500 km at 62° (Over Land)	90 to 220 Approx. These appear to be over populated areas

INTERNATIONAL SPACE REPORT

Premier Urges Strong Support



A "promising start to an ambitious project" is how the Premier and Treasurer of Queensland, Sir Joh Bjelke-Petersen, described the preliminary study into the establishment of a space launch facility at Cape York.

Sir Joh said he deplored the decline which had seen Australia go steadily backwards since 1967 after it became only the third country to launch a satellite from its own territory.

"Whilst it may appear illogical to consider space launch facilities in Australia, where space programmes are almost non-existent, a deeper examination of the problem alters this perception. I tender for consideration that other countries, who are active in Space, need improved launch facilities for operational reasons, such as limitations of terrain, weather, air traffic and other locational restrictions," he said.

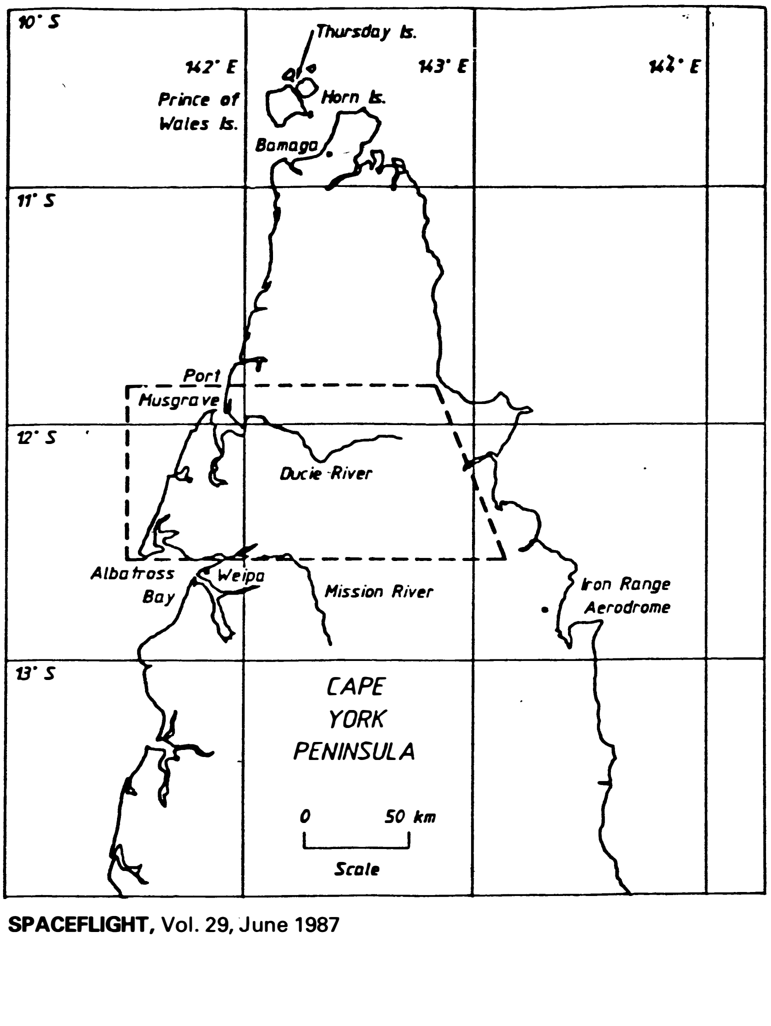
"I believe there is scope for Australia to investigate versatile facilities, which could be used by those countries developing space programmes today. A launch site established in Queensland would exploit our unique advantages of stable political environment, developed industrial and transport infrastructure, favourable geographical location, reliable weather, good radar coverage and efficient air traffic control.

"Even today, when all the developed countries (and some less developed, such as India, China, Brazil and Indonesia) have thriving space programmes, Australia has none," he added.

Study Cites Significant Advantages

Commercial space launch activities in the Western World are at a crossroads and Australia could, as a result, be presented with a unique opportunity to establish an international commercial spaceport. This situation has been brought about by a number of factors.

Figure 2: Recommended region for launch site.



- Several countries active in the development of launch vehicles are constrained geographically and politically from establishing commercial launch services. Some are known to be investigating more favourable locations for launch sites, even beyond their territorial boundaries, in order to overcome these constraints.
- The disaster of the Space Shuttle Challenger in early 1986 has forced a re-appraisal of the role the Shuttle should play in commercial space launches and has rekindled interest in expendable commercial launch vehicles in the United States.
- The decision to open the dominant US market to commercial expendable launch vehicles, and the failures in 1986 of two of the main US expendable launchers as well as the European launcher, have provided an incentive for private enterprise within the United States and for organisations in other countries to enter the relatively lucrative commercial launch business.
- A number of expendable launch vehicles capable of carrying large commercial spacecraft are either operational or in an advanced state of development in the USA, Europe, Soviet Union, China, Japan, India and Brazil. Of these only Europe (at Kourou in French Guiana) and Brazil have launch sites in highly desirable

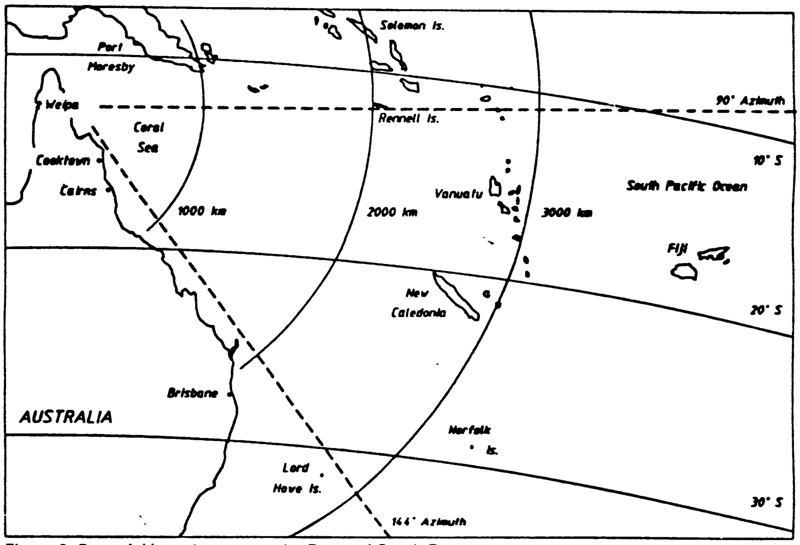


Figure 3: Potential launch sector to the East and South-East.

locations close to the equator (in the north of the South American continent).

New forms of reusable space vehicles are on drawing boards and US and Soviet Space Stations will generate their own specialised space traffic in the mid to late 1990's.

This opportunity for Australia is associated with four of its assets; the availability of a near-equatorial launch site which allows increased payload capability for launch vehicles to the commercially important equatorial orbits, the political stability and relative neutrality of the country, its geopolitical position within the Pacific 'Rim of Technology' and the sophisticated infrastructure which can be provided.

The opportunity will not last long. International discussions taking place now about launch site developments will, within a few years, determine the global launch facilities for a period extending well into the 21st Century.

The Co-ordinator-General of Queensland commissioned the Study in order to assess the feasibility of a spaceport located in an equatorial region of Australia. Although promising potential sites are situated in Queensland, the implications of the study transcend Queensland State boundaries

The Report also suggests an international, commercial undertaking; a novel approach, on the world space scene. Implementation of the concept will be a major undertaking in terms of the international collaboration and capital investment required. Further extensive investigations and negotiations will be needed to ensure its success.

The region proposed is at a latitude of about 12°S and offers advantages in in terms of meteorological conditions and access to the most important commercial orbits. The favourable climate for a launch site near the western side of Cape York Peninsula is documented in Table 1, along with comparative data for some other selected launch sites.

A further significant advantage of the proposed region is the proximity of existing infrastructure, including air and sea port facilities at the modern mining town of Weipa. Possible rationalisation of launch facilities with the airfield proposed on northern Cape York Peninsula for the Australian Defence Forces has the potential for major economies.

Figures 3 and 4 show potential launch sectors to the east and south-east over water, and to the south-west over water and desolate parts of central Australia.

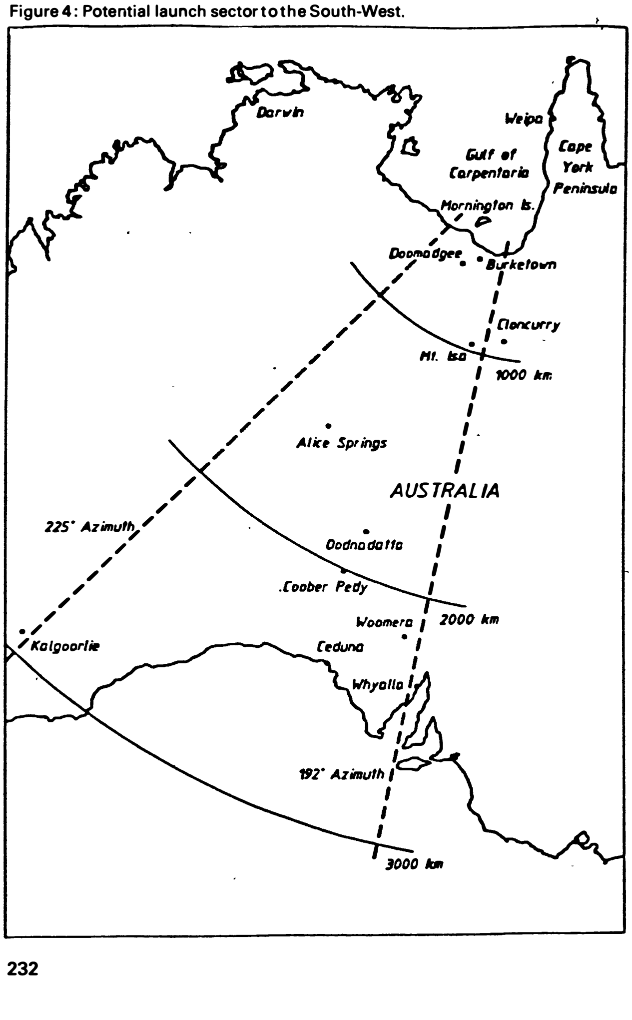
Population densities in central Australia are amongst the lowest in the world. For the routine commercial launch operations envisaged by the turn of the century the risk of mishap due to falling debris is likely to be very low. Furthermore, part of the planning of missions will be the tailoring of trajectories to avoid the few scattered population centres in the south-west sector.

The main conclusions of the Report are that Cape York Peninsula appears to offer a number of significant advantages over most existing operational sites in the world, and that present forecasts of traffic into space show a potential segment of the commercial market which Cape York International Spaceport could capture.

Various other matters which need more detailed investigation in order to confirm the viability of the proposal are also highlighted. Subsequent studies should involve participation of a broad range of interests, including government and commercial, national and international organisations. Organisational, technical, legal, trade, marketing, financial, taxation and environmental aspects are among the issues requiring further study.

Early results from the Part 1 Study, together with feedback already received from overseas interests, strongly support the Report's recommendation to proceed immediately with the next phase of the Feasibility Study.

Figure 4: Potential launch sector to the South-West.



SATELLITE DIGEST – 203

Robert D. Christy

Continued from the May 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1818, 1987-11A, 17369.
Launched: 2328, 1 February 1987 from Plesetsk possibly by D-2.
Spacecraft data: Not available.
Mission: Possibly electronic intelligence gathering.
Orbit: 786 x 800 km, 100.74min, 65.02deg.

GINGA, 1986-12A, 17480.
Launched: 0630*, 5 February 1987 from Kagoshima by M-3S.
Spacecraft data: Rectangular box-shaped body, approx 1.55 m high and 1 m across, with a "cross" of four solar panels in a plane at right angles to one face. The mass is 430 kg.
Mission: Scientific satellite studying astronomical gamma ray and x-ray sources.
Orbit: 510 x 673 km, 96.35 min, 31.09 deg.

SOYUZ-TM 2, 1987-13A, 17482.
Launched: 2138*, 5 February 1987 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module, and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried the long stay crew of Yuri Romanenko and Aleksander Laveikin to Mir. It docked with Mir's extreme forward port at 2319 on 7 February 1987.
Orbit: Initially 263 x 300 km, 90.09 min, 51.62 deg then raised to 328 x 362 km, 91.39 min, 51.62 deg for rendezvous with Mir.

COSMOS 1819, 1987-14A, 17484.
Launched: 1030, 7 February 1987 from Plesetsk by A-2
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is betewen 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 11 days.
Orbit: 209 x 255 km, 89.19 min, 72.82 deg.

USA 21, 1987-15A, 17506.
Launched: 0630, 12 February 1987 from Vandenberg AFB by Titan 3B-Agena D.
Spacecraft data: not available.
Mission: Satellite Data System vehicle providing communications between the continental U.S. and strategic forces in north polar regions.
Orbit: approx 400 x 39775 km, 717.8 min, 63.0 deg.

COSMOS 1820, 1987-16A, 17523.
Launched: 0840, 14 February 1987 from Tyuratam, possibly by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with overall length about 6 m, maximum diameter 2.4 m and mass between 6 and 7 tonnes.
Mission: Possibly military photo-reconnaissance, re-entered after 20 days.
Orbit: 180 x 252 km, 88.83 min, 64.84 deg.

COSMOS 1821, 1987-17A, 17525.
Launched: 1354, 18 February 1987 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 963 x 1016 km, 104.97 min, 82.92 deg.

MOMO, 1987-18A, 17527.
Launched: 0120, 18 February 1987 from Tanegashima by N-2.
Spacecraft data: Rectangular, box shaped body approx 1.3 x 1.4 x 2.4 m, with a single, 2 x 5 m solar panel extending from one edge.
Mission: Remote sensing, with particular emphasis on studying marine phenomena.
Orbit: 910 x 911 km, 103.27 min, 99.10 deg.

COSMOS 1822, 1987-19A, 17533.
Launched: 1015, 19 February 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 193 x 306 km, 89.53 min, 72.88 deg.

COSMOS 1823, 1987-20A, 17535.
Launched: 0445, 20 February 1987 from Plesetsk possibly by F-2.
Spacecraft data: Possibly similar to the navigation satellites in having a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Probably a geodetic satellite.
Orbit: 1481 x 1524 km, 116.09 min, 73.62 deg.

COSMOS 1824, 1987-21A, 17559.
Launched: 1330, 26 February 1987 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded container may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 700 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 165 x 355 km, 89.72 min, 67.17 deg, manoeuvrable.

GOES 7, 1987-22A, 17561.
Launched: 2240, 26 February 1987 from Cape Canaveral AFS by Delta 3920.
Spacecraft data: Spin-stabilised cylinder, 2.15 m in diameter and 3.12 m long. The mass is 397 kg (excluding fuel).
Mission: Meterological satellite returning cloud cover images and other atmospheric data.
Orbit: Geosynchronous above 83 deg west.

Inmarsat Finalises Aeronautical Station System

Inmarsat has finalised system specifications and established space segment charges for its satellite communications services which will be offered to the world's airlines and civil aircraft. Meeting in London recently, the Inmarsat Council approved specifications and charges for the use of Inmarsat satellites for aviation communications.

Inmarsat is a 48 member-country consortium currently operating a system of nine satellites for maritime and other mobile communications. Initially, the new aeronautical services will be provided using Inmarsat's existing satellites, although the organisation already has under construction three Inmarsat-2 satellites with expanded capacity and the capability of operation in frequency bands set aside exclusively for aviation use.

Aeronautical services will include worldwide data and voice communications for aircraft operations and traffic control, as well as passenger telephone and data links.

Three of Inmarsat's member countries – Norway (also representing Denmark, Finland and Sweden), Singapore and the United Kingdom – have already announced plans for equipping aeronautical ground stations (AGSs) for operation in 1988.

"We are planning to begin technical testing of the system, using specially installed airborne and ground equipment during the latter part of this year and at least two airlines – British Airways and Japan Air Lines – have announced their intention to offer pre-operational passenger telephone services in early 1988," said Mr. Olof Landberg, Inmarsat's Director General.

The world's aeronautical community has been talking about satellite communications for so long that the appearance this year of the first concrete services may seem a less dramatic event than it really is. But the fact is that a series of experiments and service trials about to be carried out by airlines and aviation industry organisations could, as soon as the end of this decade, revolutionise flying for everyone aboard an aircraft from the cockpit to the passenger cabin.

Interest in aeronautical satellite communications has heightened considerably over the past few years, stimulated by the rapid evolution of terrestrially-based aeronautical communications offering automatic voice and data services.

New Jobs for Space Men

NASA Chief Astronaut John W. Young has been appointed Special Assistant to the Johnson Space Center Director for Engineering, Operations and Safety.

In his new position, Young will have direct and immediate access to the Center Director Aaron Cohen and other senior managers to aid in the timely definition and resolution of issues affecting the safe return to flight of the Space Shuttle.

Young (56) will also advise the Center Director on engineering, operational and safety aspects of Space Station and new initiatives such as the second generation shuttle and the national aerospace plane.

As the United States' most experienced astronaut, with six space missions spanning the Gemini, Apollo and Space Shuttle eras, Young will remain eligible to command future Shuttle astronaut crews.

* * *

Following Young's appointment four astronauts have been assigned to key posts in the Flight Crew Operations Directorate and Astronaut Office at the Johnson Space Center.

They are: Henry W. Hartsfield, Deputy Director for Flight Crew Operations; Daniel C. Brandenstein, Chief of the Astronaut Office; Karol J. Bobko, Assistant for Operations to the Director, Flight Crew Operations; and Steven A. Hawley, Deputy Chief of the Astronaut Office.

* * *

Dr. Paul Williams (53) has been appointed Director of the Science and Engineering Research Council's Rutherford Appleton Laboratory (RAL) in the UK. He has been Acting Director since December 1986.

* * *

Englishman Mr. Geoff Hall has been elected chairman of the Council of the International Maritime Satellite Organisation (Inmarsat), succeeding Mr. John Feneley of Canada. Mr. Hall is currently Head of Satellite Systems (Planning and Policy) in British Telecom International.

* * *

Joseph P. Kerwin, NASA astronaut since 1965, has joined Lockheed Missiles & Space Company as chief scientist for the company's Space Station programme.

Proton's Fourth-Stage Fails Again

The problems experienced with the fourth stage of the Proton booster launched on January 30, 1987 (*Spaceflight*, April 1987, p.165) were thought to have been overcome following the successful launch of a communications satellite on March 19, 1987.

However, during a Proton launch on April 24, 1987, a premature shutdown of the stage left an expensive payload of three Glonass navigation satellites in a transfer orbit of reduced altitude.

The Proton's fourth stage serves to propel a payload from low-Earth orbit to geostationary orbit, first being fired to achieve a transfer orbit and then again later to circularise the orbit at the required altitude. The mission of April 24 is now unlikely to be saved as attempts to refire the fourth stage and so raise the orbit have not succeeded.

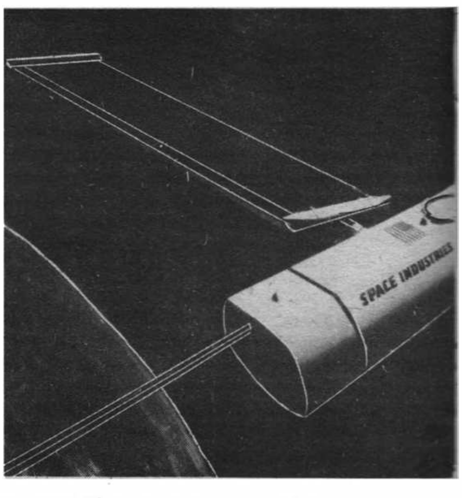
As with the previous failure, Soviet statements about the launch have tried to minimise any adverse effect on the efforts of their Glavkosmos organisation to market an international launch service using Proton.

French Payload for China

A package prepared by France's Matra is to be carried as a 15 kg piggyback experiment on a recoverable satellite to be launched by a Chinese Long March 2 in August.

The purpose of the experiment is to evaluate onboard accelerations during the launch phase and also the microgravity environment during the capsule's five day stay in orbit.

If results are satisfactory, the cooperative effort is expected to lead to two or three commercial microgravity flights per year with the possibility of an increase in payload on a Long March 3 launcher.



Canadian Telesat Launches

Canada's next communications satellites, Anik E1 and Anik E2, will be launched in 1990 aboard two Ariane 4 launch vehicles, each equipped with four solid booster rockets.

The two Aniks, Telesat's 10th and 11th, will be the first Canadian satellites ever launched by Arianespace. Each requires a dedicated launch aboard an Ariane 44P, one of the most powerful European launch vehicles..

When launched the Anik Es will be the largest, heaviest and most powerful dual-band communications satellites ever built for a domestic satellite company. Spar Aerospace is now building the satellites at its plant near Montreal. They will be completed by 1989 and launched in the spring and autumn of 1990 from the Guiana Space Centre near Kourou, French Guiana.

Anik E1 will come into service in 1990 while Anik E2 will be kept in a storage orbit until 1992. The satellites are designed to meet Telesat's communications requirements until at least the year 2000. They are dual-band satellites, capable of simultaneously relaying the equivalent of 56 television channels at C and Ku band frequencies. The satellites will be used to transmit television, radio, telephone and data communications for Telesat's broadcast and telecommunications customers throughout Canada and between Canada and the United States.

Anik A1, launched in 1972 was the world's first domestic geostationary communications satellite. Since then Telesat, a private Canadian company, has owned and operated eight additional satellites, more than any other domestic satellite company in the world. Telesat currently has five Anik satellites in orbit.

Indian Contract for UK

A £1.5 million contract from the Indian Space Research Organisation has been received by UK firm IGG Component Technology of Cosham, Hants.

It is for the supply and testing of high reliability components for the Insat II satellite, the second satellite, forming part of the Indian drive to improve and extend television broadcasting and communication services across the sub-continent.

The contract is the latest in a series won by IGG over recent months. The company, the largest independent specialist in this field in Europe, has contributed to numerous European space projects, including Italian, French and European Space Agency programmes.

Experiments Selected for Comet Investigation

Three experiments submitted by scientific teams at NASA's Ames Research Center have been selected by an international panel of scientists for participation in the study of comets.

The Comet Rendezvous Asteroid Flyby (CRAF) mission, being considered for launch in the early 1990's, will be the first of the new Mariner Mark II series of spacecraft. It will rendezvous with a short-period comet several years after launch and fly with the comet for three to four years. The principal mission objective is to characterise the nucleus of the comet.

Ames' three CRAF proposals are: the cometary ice and dust experiment (CIDEX), thermal infrared radiometer experiment (TIREX) and an interdisciplinary scientist for exobiology (IDS).

The CIDEX instrument is designed to capture and analyse dust, ices and gases evolved from the comet as the coma and tail develop during its pass around the Sun.

TIREX will directly measure the thermal emission and the scattering of solar radiation from the comet. This will greatly enhance understanding of cometry radiative effects and allow for refinement of comet energy budget models. Spectrally resolved observations of the comet also will provide information on the composition and particle size distribution of the coma dust.

The IDS for Exobiology, proposed by Dr. Christopher McKay, involves the study of those chemical processes and physical events that led to the appearance of life in the universe. Included is cosmic history of carbon and other biologically important elements, chemical evolution of the first biochemical systems and the early origin and evolution of life.

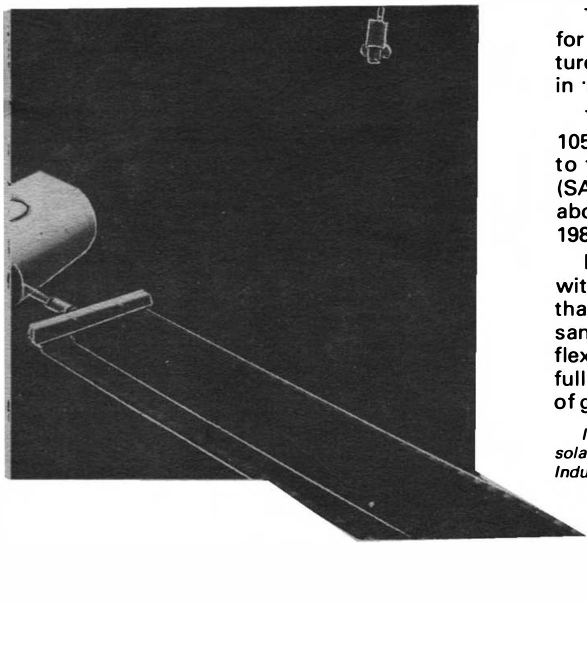
McKay's role is to represent the scientific interest of exobiology throughout the mission. He will assist CRAF instrument teams and project science groups, and aid in CRAF flight data interpretation, to ensure that exobiology science objectives are included.

McKay will also seek to determine the organic content of the nucleus; understand the distribution of the biogenic elements and their compounds in the nucleus and determine the dynamic evolution of the biogenic elements in the nucleus during approach to the Sun.

The Comet Rendezvous Asteroid Flyby (CRAF) mission study is managed by NASA's Jet Propulsion Laboratory (see ***Spaceflight***, Feb. 1987, p.80).

Orbiting Power Module

Lockheed engineers are beginning the second phase in the design of a 28 kW power module for an Industrial Space Facility scheduled to be placed in orbit in the early 1990s.



The facility is expected to be used for materials research and manufacture and for testing space technology in a microgravity environment.

The power module will have two 105 ft flexible solar array wings, similar to the Solar Array Flight Experiment (SAFE) that was successfully tested aboard a Shuttle flight in September 1984.

Each of the wings will be covered with nearly 30,000 silicon solar cells that are welded to a printed circuit sandwiched between two layers of flexible Kapton plastic. When struck by full sunlight each wing will be capable of generating 14 kW of electricity.

In the artist's conception (left) two flexible solar arrays convert sunlight into electricity for the Industrial Space Facility.

Space Walk Saves Mission

Cosmonauts Yuri Romanenko and Aleksander Laveikin completed a 3 hour 40 minute spacewalk on April 12, Cosmonautics Day, which succeeded in ensuring the firm docking of the Kvant (Quantum) astrophysics module with the rear docking unit of the Mir complex.

by

Neville Kidger

The walk can be compared with the mission-saving work done by US astronauts Conrad and Kerwin in 1973 which made the Skylab space station usable for long duration missions.

Kvant the rear-mounted module shown by the Soviets at their training centre (picture below) was launched on March 31. Initial attempts to dock it with Mir were made on April 5 but a problem developed which forced an abort of the docking. After corrective measures, the docking did take place on April 9 but was not made hermetically with the station. A decision was then taken by controllers at the Soviet Flight Control Centre to attempt a spacewalk to see what the problem was.

The cosmonauts reported that an "extraneous" object had lodged between Mir and the module. The men removed it and the two spacecraft were firmly docked.

A more detailed description of the space walk will follow in a subsequent issue. The following report covers the activities of the cosmonauts from mid-February to the launch of the Kvant module.

Manned Mode

By the end of their first week in orbit Romanenko and Laveikin had conducted all the scheduled operations to bring the station into a manned operational mode and had taken stock of the expendable materials onboard. They were continuing to unload the materials delivered by the Progress 27 cargo spacecraft and had made requests to the staff at the Flight Control Centre for various items to be sent to them on the next cargo spacecraft, including videotapes of Soviet entertainers.

An interesting ocean phenomena was observed by the two cosmonauts in mid-February. They saw "powerful concentric waves" emanating from an area of the ocean which displayed a "serene surface". The eight or nine waves were estimated to have been 2-300 km across. The observation was reported on February 15 whilst the men were preparing the engine of the station for automatic refuelling by the Progress cargo spacecraft.

A medical check on February 16 with the Gamma-1 apparatus showed that the men were both in good health and were involved in regular medical monitoring. Earlier, about one week after arriving on Mir, Laveikin had suffered "a rather painful" adaptation to weightlessness and, according to Soviet statements, "needed rest particularly badly". The disclosure was unusually frank, contrasting with NASA policy of not discussing the state of health of US astronauts to maintain personal privacy. The exception to NASA's rule would occur if an illness were mission-critical or if it affected specific mission goals.

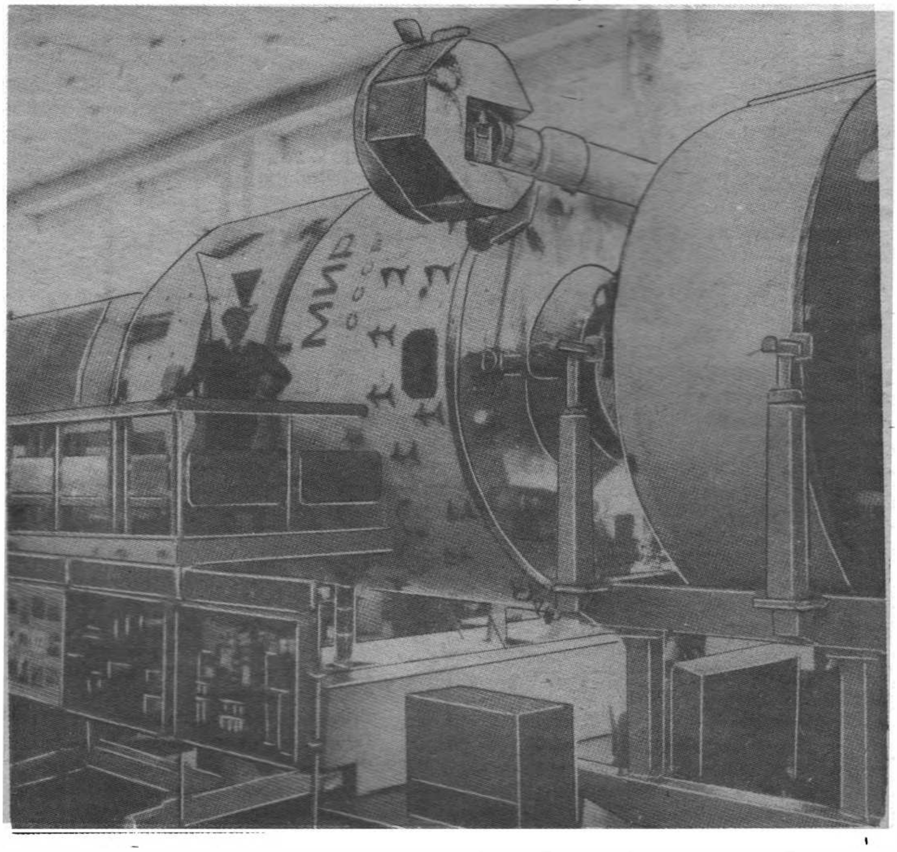
On February 18 the cosmonauts installed additional equipment in the station's power supply system, pumped drinking water from Progress into Mir and prepared transfer lines for the refuelling of the oxidiser tanks of the station. The refuelling was complete the next day and the Soviets said that Progress 27 would leave the complex "soon". On February 20 the engines of the cargo ship were used to manoeuvre Mir and Soyuz TM-2 into a higher orbit.

Early on February 23 it was announced that the Progress 27 cargo ship would separate from the complex later that day. The separation occurred at 1129 (all times GMT). The engine of the cargo craft was switched on at 1517 on February 25 and it subsequently burned up in the upper layers of the atmosphere.

It was reported that the previous day, February 24, Romanenko and Laveikin had donned their space suits during an unspecified experiment which may have been related to the announced intention to "assemble large units in raw space".

The first photographs of the Earth's surface to be taken on this flight were obtained on February 26 with "a new fixed camera and portable apparatus". Photography of unspecified areas continued over several days.

A mockup at the Yuri Gagarin Cosmonauts' Training Centre of the Mir Space Station with the astrophysics module, Kvant, attached. The module was launched by a Proton rocket on March 31, 1987 and subsequently docked with Mir. *Novosti*



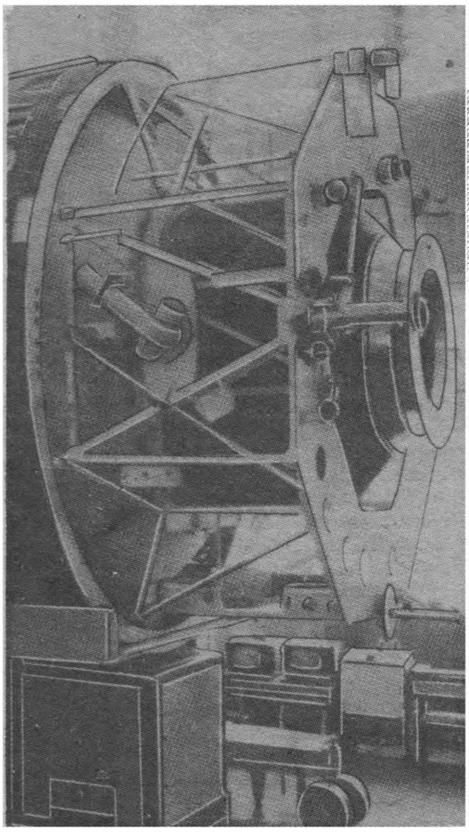
SOVIET SCENE

Progress 28 in Flight

On March 3 the Soviets announced that another Progress spacecraft was to be launched that day from Baikonur. Launch occurred at 1114 and Progress 28 was placed into a low-Earth orbit from where it was manoeuvred over the next two days to an automated docking with the aft docking unit of the Mir station at 1243 on March 5.

The cargo ship delivered over two tonnes of various cargoes and consumables, including personal items and mail for the two cosmonauts. Amongst the scientific equipment delivered was KATE-140, a topographic mapping camera, several spectrometers and Korund, a semi-industrial materials processing unit with a weight of 136 kg. Using this it is intended to produce unique crystals for use in the Soviet electronics industry and other sectors of the Soviet hitech economy.

The microgravity conditions aboard Mir have already been used by Romanenko and Laveikin to conduct experiments with PION-M to study the processes of heat and mass transfer in a liquid media. These experiments are related to the Soviet intention of producing large volumes of biological and metals samples in space, eventually leading to production in economic quantities on special factory modules. In the course of the various experiments with the PION-M unit the cosmonauts have, according to one Soviet scientist, "moved us into a yet unexplored field of colloidal chemistry".



The Soviets have opened a special telephone line for citizens to phone and hear news about the Mir cosmomauts.... Moscow 2156356.

In one TV broadcast the cosmonauts showed viewers an onion that they had grown in the station since occupying it but revealed that other plants planted in special hothouses had yet to develop shoots as the onion had.

On March 9 the engines of Progress 28 were used to manoeuvre the station into a new orbit with a height of 386 x 355 km and an orbital period of 91.7 minutes.

By March 13 the cosmonauts had completed the installation of the Korund unit and had conducted further Earth observations. The water delivered by Progress had also been pumped into the station's onboard tanks.

The first Korund experiment was completed by March 17 and Earth observations continued to occupy the men for another week, particular attention being paid to the medium and southern latitudes of the USSR. The cosmonauts used the KATE-140 camera to observe the groundtrack directly under the station and the camera system called "Sever" to take pictures to the side, recording geological features obliquely and with greater relief.

At 0507 on March 26 Progress 28, which had been used on two occassions to raise the orbit of Mir, was undocked. Two days later, at 0259, the engines were ignited again and the spacecraft fell from orbit to be destroyed in the upper layers of the atmosphere as all the previous cargo ships had done.

Romanenko and Laveikin continued with work on the PION-M and Korund units.

Kvant – A New Name in Orbit

Early on the morning of March 31 a Proton rocket put into low-Earth orbit the Kvant module which the Soviets identified as the first special-purpose space module for the Mir station. It was to dock with Mir on April 5 (***Spaceflight*** May 1987, p.184).

TV pictures of the two Mir cosmonauts examining the module on the ground in the Assembly Building at Baikonur showed that it was the aft-mounted module previously seen at the training centre in Moscow (see picture).

The Soviet description of the module at the time of the launch said it consisted of two coupled vehicles: the module proper and what was termed a Functional Auxiliary Block (FAB). Together, both weighed 20.6 tonnes. During independent flight the module is the passenger of the FAB. Six manoeuvres, rendezvous and docking were all to be conducted by the FAB. After docking and initial checks of the auxiliary systems of the module the FAB is undocked leaving the module's rear docking unit free to receive manned and unmanned spacecraft.

The Kvant module itself weighs 11 tonnes, is 5.8 metres long and 4.15 metres in diameter. It consists of a laboratory compartment with a transfer chamber and research equipment compartment. Inside the laboratory compartment there are instrument and living sections divided by interior panels. It features one digital and two other computers. The laboratory compartment and the transfer compartment form air-tight quarters of 40 m^3 volume. The scientific payload bay is not hermetically sealed and the battery of astrophysical telescopes is organised in this bay around the docking unit and transfer compartment. The module carried 1.5 tonnes of scientific instruments and over two tonnes of unspecified equipment to add to Mir's capabilities.

The laboratory compartment accommodates the main research equipment and a number of control systems, including steering, rendezvous and docking, and life-support (including temperature and air mixture regulators). It also contains radio, telephone, telegraph and television equipment.

The laboratory has two viewports. One, with a diameter of 43 cm is intended for an optical device, and the other, 22.8 cm in diameter, will house a visual star tracker. Two 8 cm portholes in the transfer compartment will be used for visual observations.

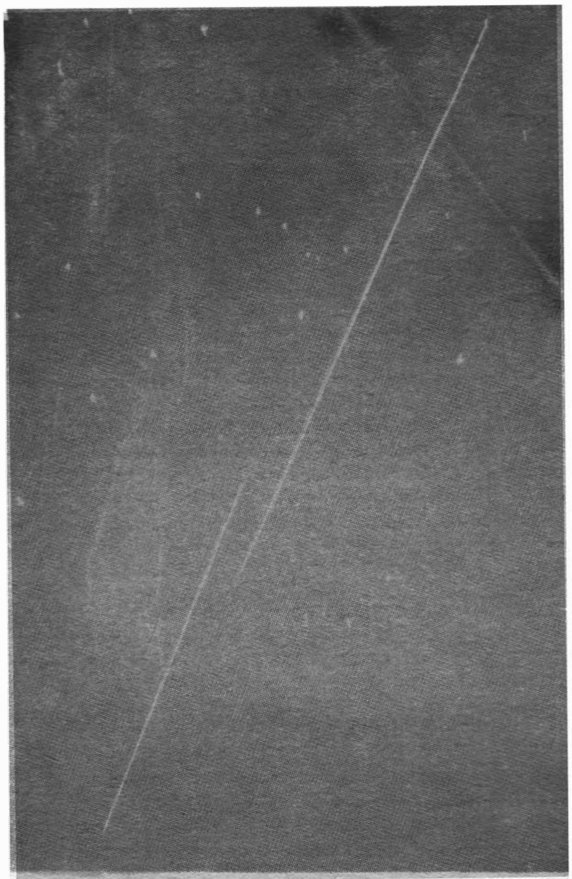
The transfer compartment includes an air-lock chamber for servicing the Glasar ultra-violet telescope and its control console. The scientific payload bay, around the transfer compartment, is intended to house instruments needed to be exposed to open space.

The payload included the 800 kg Roentgen observatory, four astrophysics telescopes (***Spaceflight*** April 1987, p.184), the Glasar UV telescope developed by Swiss and Soviet experts, and a Soviet automated, externally-mounted, electrophoresis unit named Svetlana (after Svetlana Savitskaya who conducted pioneer Soviet research in electrophoresis techniques on her two flights to Salyut 7).

To Be Continued

SOVIET SCENE

Space Stations in Formation



The two photographs reproduced on this page show the Mir and Salyut 7 space stations recorded on a single image as they passed over southern England.

They were taken by BIS Fellow Alan Lawrie who believes that this is the first time pictures of two space stations flying in close formation above the Earth have been published.

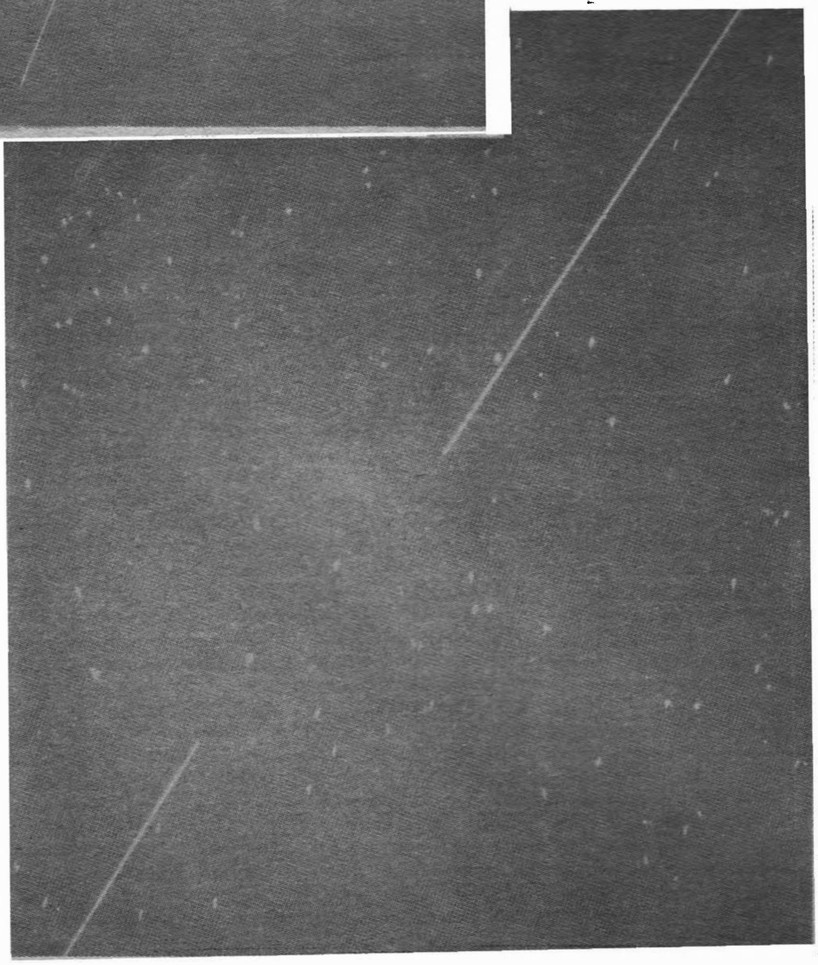
The photograph below was taken at 2255 GMT on June 26, 1986. The Mir-Soyuz T15 complex (bottom of the picture) is leading the Cosmos 1686-Salyut 7 complex (top of the picture) by about 15 seconds. The spacecraft are at an elevation of 60 degrees above the horizon moving from the top to the bottom of the photo.

The photograph at left was taken three minutes later and shows the spacecraft approaching the Eastern horizon. Mir at the bottom of the photo is still leading Salyut 7. The space stations are travelling from the top to the bottom of this 20 second exposure.

The photographs were taken just three hours after the docking of Soyuz T15 to Mir which completed the second successful transfer of cosmonauts Leonid Kizim and Vladimir Solovyov from one space station to another. It was only during the relatively short periods of time when the two space stations were close to one another that such transfers were undertaken.

The photographs were taken from Hitchin in Hertfordshire using a Pentax KX camera fitted with a 50 mm lense. The aperture was set to f1.7 and the film used was Boots ASA 1000 colour transparency film (reproduced here in black and white).

Pictures of Salyut 7 and Soyuz T15 flying in close formation were also carried in the Sept/Oct. 1986 issue of ***Spaceflight*** (see p.346) taken by reader Daniel Fischer. However, these did not show both space stations on the same image.



Mir Complex Extended to Four Units

An automatic transport ship Progress 29 was launched at 19.14 (Moscow Time) on April 21 to dock with the Mir complex, delivering expendable materials and various cargoes.

Progress 29 went into an orbit with the following parameters: period – 88.7 mins, apogee 257 km, perigee 194 km, inclination 51.6 degreees and docked with Mir at 21.05 (MT) on April 23.

The arrival of Progress 29 meant that for the first time a research complex of four spacecraft integrated into a single whole had been built in space through successive dockings. The complex consisted of the base station (Mir), astrophysical module (Kvant), a manned spaceship (Soyuz TM 2), and the automatic freighter (Progress 29).

Progress 29 carrying fuel, food, water, equipment and mail, was docked to the Kvant module.

By April 27 Romanenko and Leveikin had completed the unloading of Progress 29 and were preparing for two spacewalks to assemble an additional solar battery brought in two sections with the Kvant module.

SOVIET SCENE

The Concept of Orbital Laboratories

Almost 30 years ago, in the pre-space flight age Academician Korolev described his concept of space development in the following words: "The first flights (to outer space) will be followed by a permanently manned orbital laboratory whose staffers will make systematic observations and stage experiments hundreds of kilometres above the surface of the Earth."

by German Konstantinov

Photograph taken by the Meteor "Nature" Soviet satellite. In the bottom right corner is the Caspian Sea.
Novosti

And these long-stay space stations, where crews come and go, and technologies evolve have come along.

Electronics have reached a high level of compactness: a small plate measuring a single square centimetre can accommodate up to 100,000 "components". It will soon be possible to fit a million elements into a single crystal. But such a crystal has to be ideal – it could not be produced in Earth-based laboratories because of convection resulting from the force of gravity. However, crystals produced in outer space (where conditions rule out convection) are vastly superior. This was experimentally confirmed in the Splav and Kristal units aboard Salyut stations. Other experiments have shown that special quality drugs can also be produced in orbit at a lower cost.

Space photography is another economic advantage to be obtained from orbital laboratories. In the future "agricultural satellites" designed to monitor woods and plantations, soil humidity and crops will yield tangible profits. This type of work has already been tested by crews aboard orbital stations.

For example, one of the Soviet Central Asian republics planned to enlarge its cultivated area but remote sensing showed that the project would be an economic failure due to the shortage of water in the region and the prohibitive cost of artificial irrigation.

Another job for space technology is to monitor the pollution of the atmosphere. Under a Soviet programme the State Committee of Hydrometeorology and Environmental Control uses space photographs to advise on the most polluted city districts, woods and plantations, and the degree of smoke contamination. Equally important is the fact that regular observations show the dynamics of the process and such work is paving the way to a large-scale biosphere monitoring network.

Practical cosmonautics has come a long way. Exploitation of the opportunities now offered by the Mir space station will be the best proof that Sergei Korolev 's ideas become a reality.

Man's Role in Space Exploration and Exploitation

The International Space Station will provide long-term operations with enhanced habitability and many new specialised facilities. Crew productivity will be aided by automation and robotics. Automated systems, in turn, will be supervised by the crew to operate optimally as mission or experiment objectives change.

by Joseph P. Loftus

Assistant Director (Plans) of the Lyndon B. Johnson Space Center, Houston

The Station, like the Shuttle and other large facilities such as the Hubble Space Telescope, will not have a singular mission. It is intended to serve many payload missions over its operating life. Its effectiveness in performing these functions will depend upon maintaining a balance between the use of automated and robotic systems and the need for the crew to intervene as necessary to repair, modify, or re-program the systems.

Space Station design aims at a minimum of crew activity to maintain and operate the station so that most of the crew time can be devoted to productive activities.

The Changing Role of Space Crews

In each succeeding spacecraft design, the crew has become increasingly the 'manager' of automated systems.

The magnitude of this trend is illustrated in Table 1, which quantifies the growth in work stations, control display elements, and computational capability in each succeeding US manned spacecraft.

In this table, a work station is a crewman location where an array of tasks is to be performed. A panel is a work surface with a group of functionally-related control and display devices. A control/display element is any one of a number of devices from a two-position toggle switch to a multifunction display device such as a cathode-ray tube (CRT) or a three-axis flight director attitude indicator. Computers are digital computational devices and computer modes are functional software units such as flight control, navigation, systems management. etc.

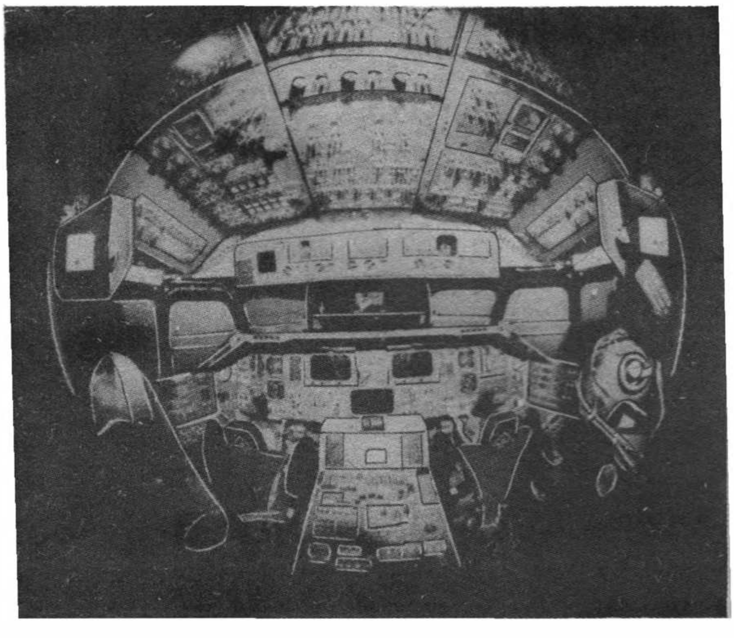
The table indicates the increasing complexity of manned spacecraft as the mission has evolved from testing man's endurance to achieving specific mission objectives. The Space Station system is to be a highly distributed, regionally autonomous system, with eight units on the primary local area network, each supporting a regional set of functionally or physically separated suite of subsystem micro-processors.

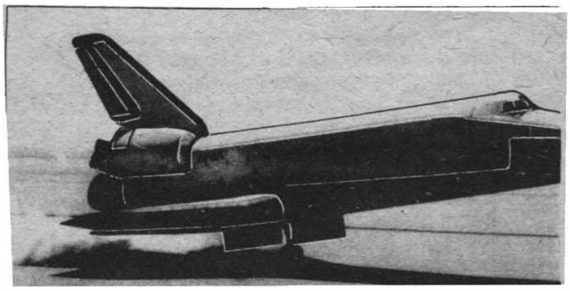
A view of the commander and pilot's flight stations in the Orbiter is shown in below left. The appearance is not unlike that of a widebody jet aircraft; but to a far greater degree than aircraft, actuation is effected via the computer rather than directly.

Table 1: Crew displays and controls.

Spacecraft	*Work station*	*Panels*	*Control display elements*	*Computers number/modes*
Mercury	1	3	143	0
Gemini	2	7	354	1/1
Apollo	7	40	1374	[a]4/50
Skylab	20	189	2980	[b]4/2
Shuttle Orbiter	9	88	2312	5/140
Space Station[c]	40	200	3000	8/200

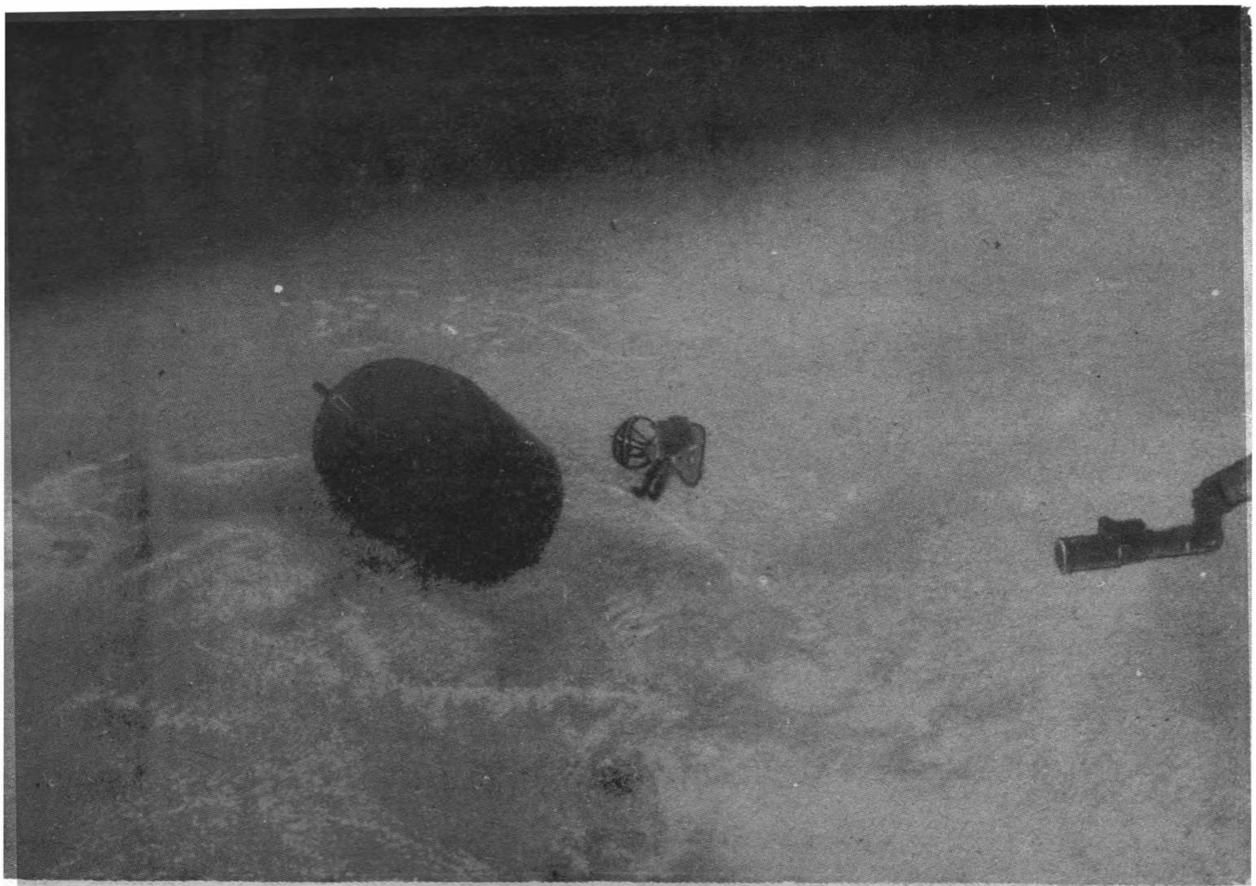
[a]Primary, backup in CM and LM
[b]CM primary and backup, telescope, workshop
[c]Assumes real-time control onboard, data base management from the ground





The Shuttle Orbiter (above) is equipped with TACAN (Tactical Air Navigation) aids, providing early azimuth and slant range distance to a beacon near the landing site. Terminal area navigation is, by inertial navigation, updated by TACAN and the Microwave Scanning Beam Landing System, which provides precision altitude and azimuth data near the runway. Automatic landings are feasible; but if the pilot is not active during landing, transition time constants preclude reversion to manual control in the event of a failure of the automatic system.

This wide-angle photograph (left) of the Shuttle Orbiter's primary controls and displays illustrates the prominence of the three CRT displays (left, right, and centre, below the window sunscreen) and the command and query entry keyboard for the commander and pilot, located on the central console below the central CRT. Many of the switches visible are, in fact, commands to the central computer, with conventional switches used to keep the crew appraised of current system state.



The recovery of a failed satellite has a uniquely defined set of activities to effect capture and repair, or retrieval and return to Earth. This picture illustrates the approach by astronaut George Nelson to the Westar communication satellite as the orbiter and remote manipulator station-keep to assist in capture and retrieval.

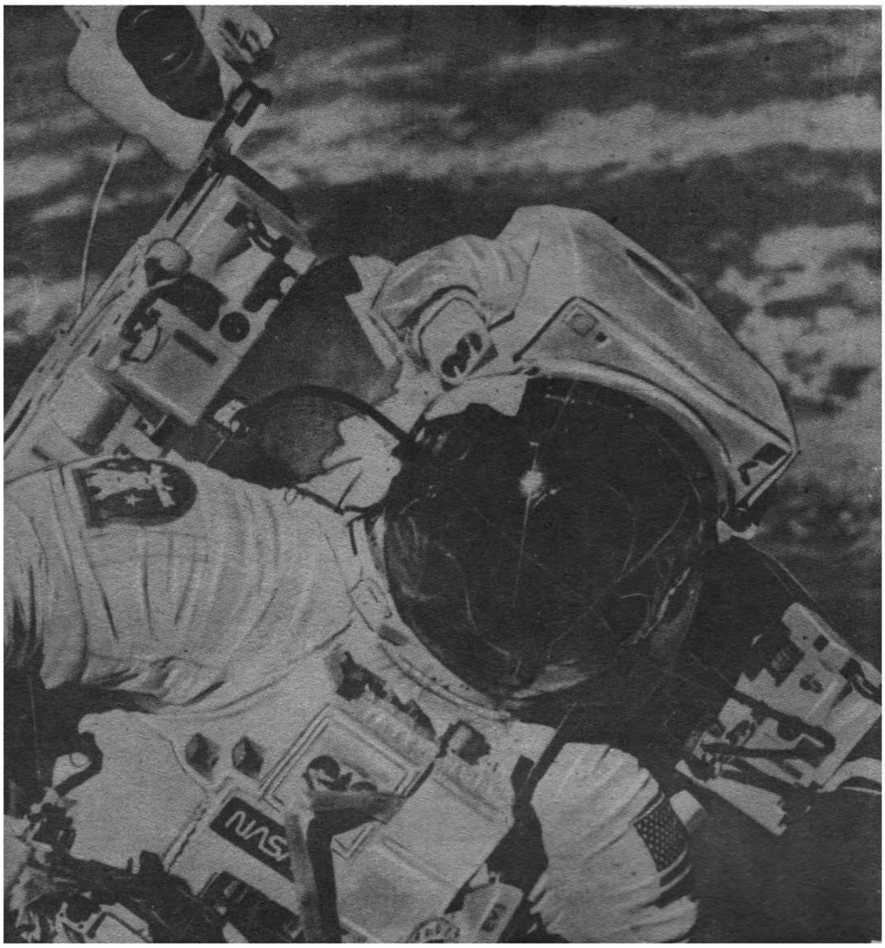
As an indication of the reliance of space flight design on manned operations, it should be noted that STS-1 was the first manned spacecraft to fly its initial flight manned. In earlier programmes, an automated system was flown first.

In Mercury, the pilot had mechanical actuation of the attitude control thrusters; in the Shuttle, the control stick and most switches set commands in the primary computer system and its software for implementation via a data bus. As the manager, the crewman participates in some control loops and monitors others; but, increasingly, his role is as an arbiter rather than as a direct operating element, i.e. direct sensor or effector. The crew is active in the control loop because that assures currency of judgement as to system state and minimises transition times if switching is required.

There are still a few instances where elemental hands-on flying is required, as in capturing derelict spacecraft and in Shuttle landings. These examples illustrate two different basic issues. In manoeuvring to recover failed spacecraft, crew control is dictated by the unanticipated character of the event and the unique characteristics of each instance, which make automation of such functions prohibitively expensive and cumbersome. In order to recover the spacecraft, one crewman in the manned manoeuvring unit flew to the spacecraft, captured it with a probe that went into the engine nozzle, and delivered it to the other EVA crewman who was to attach an adapter.

In the case of Shuttle landings, the

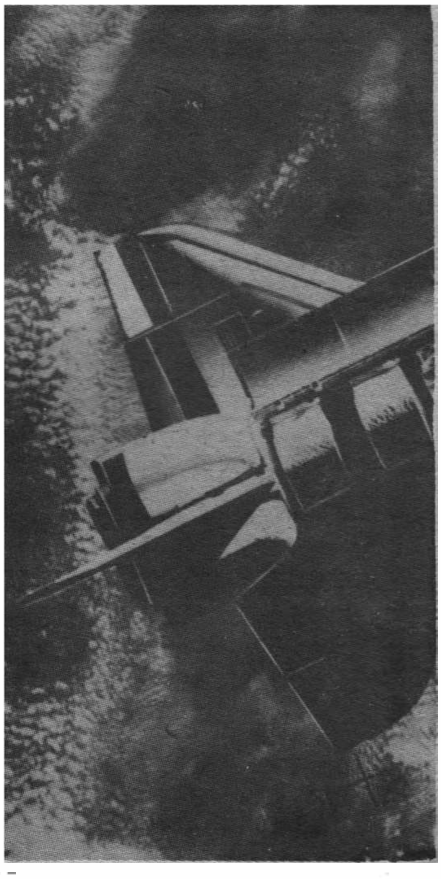
The Mission Control Center shares a significant amount of data as to spacecraft status via telemetry. This extended crew can make the mission more efficient by off-loading non-essential tasks from the flightcrew. The picture below shown operations during an EVA.



Astronaut Bruce McCandless during operation of the Manned Manoeuvring Unit (MMU) in February 1984 on mission 41B.

expensive to build, verify, and operate such software than it is to produce the flight-specific software [1]. The factory itself uses almost three million source lines of code (SLOC). Three hundred thousand SLOC were custom-developed, and the balance is existing commercial products.

Preparation for a Shuttle flight involves setting into the flight software initialisation, as many as 7,000 coefficients unique to the time of launch, the particular vehicle, the characteristics of the payload, and arising from changes in other mission parameters. For a normal case, about 1500 such values need to be set. These changes are required because the structural stiffness of the Orbiter, which is a function of the cargo it carries, and the bending modes enter into the flight control laws.



issue becomes one of crew capability to displace a failed automatic system not actively in control during a time-critical manoeuvre. Since the Shuttle has no jet engines, it cannot go around and attempt a second approach; all landings are dead stick. Therefore, two issues develop: transition time constants if the automatic system fails and the crew must intervene, and the level of crew training and readiness to do a manual landing. To assure crew capability to manage the landing and take control in the event of any system failure, the landing is generally done in a control-stick-steering flight control mode that is a blend of crew commands and the automated system.

The flight control team on the ground is a complement to the crew in-flight. For example, all communication switching and circuit control is done on the ground where circuit margin performance can be measured. Activity planning is coordinated between the flight and ground crews, and the ground's role is particularly intense when an anomaly is to be resolved. When the mission proceeds according to plan there is minimal demand of the Mission Control Center. When anomalies occur, the ground can assist the on-board crew to diagnose the fault and define a workaround. The ground can also re-plan the mission to reduce the impact of the anomaly while the crew sleeps or pursues other duties [2].

Trends in Space Computer Systems

The Shuttle is the ultimate embodiment of our ability to automate, as captured in mid-1970's technology. It has a quadredundant set of central processors that are essentially asynchronous; that is, priority interrupt occurs as needed or is situation determined, not just permitted at clocked intervals. Otherwise, we could not get the lift and structural performance required during ascent and descent through the atmosphere. An independent backup system parallels the primary system to guard against a systematic flaw in the primary system software.

The Shuttle is the first major space flight system dependent on embedded software. In earlier systems, the design was such that hardware could be operated with various types of direct controls and to automate, meant to have the computer use or bypass those controls. In a system with embedded software, there are no direct controls; there is only access via the computer. Many such systems are commonplace today; microwave ovens and video cassette recorders are good examples.

With reference to large complex systems such as the Space Shuttle or a space station, few appreciate the cost of the factory for software required to produce and then verify error-free operating software. It is over one-half of the factory cost to produce such flight-specific software, i.e. it is more

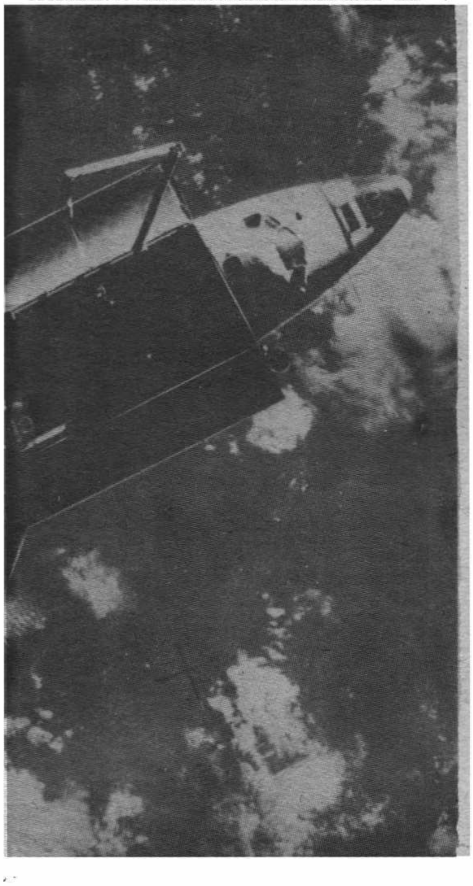
Therefore, the trend in space systems is much like that in other sophisticated flight vehicles and process control systems [3] and involves:

- Increasing the automation of those functions that can be defined, with the crew supervising and programming the system.
- Increased reliance on operating crews for decision management and more effort to provide the information to support such decision-making functions.

As an interesting aside on the nature of such information let me sum-

marise a lesson learned. We found by experience that the crew needs the sense of location that we provide in the Mission Control Center with a Mercator projection map and the current projected ground track. The crew now carries a Grid Compass Computer with that display. It projects the same view as that obtained from looking through the Orbiter window. When one is elsewhere in the spacecraft it is hard to keep aware of ground track, yet many activities are keyed to such local conditions. Availability of the display has substantially enhanced productivity.

● Increased reliance on computer input and output devices to assess system state, modify or direct the system and to assess task accomplishment. This has generated a whole new family of issues regarding the most effective way to provide interfaces between the automated and crew-controlled functions.



A unique view of the Shuttle as it orbits the Earth as seen by an astronaut using the MMU.

EVA

The design of new spacecraft, such as the "great observatories" that will characterise our astrophysics programme for the next 20 years, all rely upon periodic servicing and modification on-orbit. The telescope of the Hubble Space Telescope is a three metre diffraction limited collector. No given set of focal plane spectrographs or other instruments can fully exploit its gathering power.

Once established in space, it is not desirable to subject it to the stress of entry, landing, or another launch. Therefore, the plan is to change focal plane instruments periodically, as required by failure or incentive for new discovery. Similar servicing will support the Gamma Ray Observatory, the Advanced X-ray Astronomy Facility, and the Shuttle Infrared Telescope Facility for both new instruments and the replenishment of consumables.

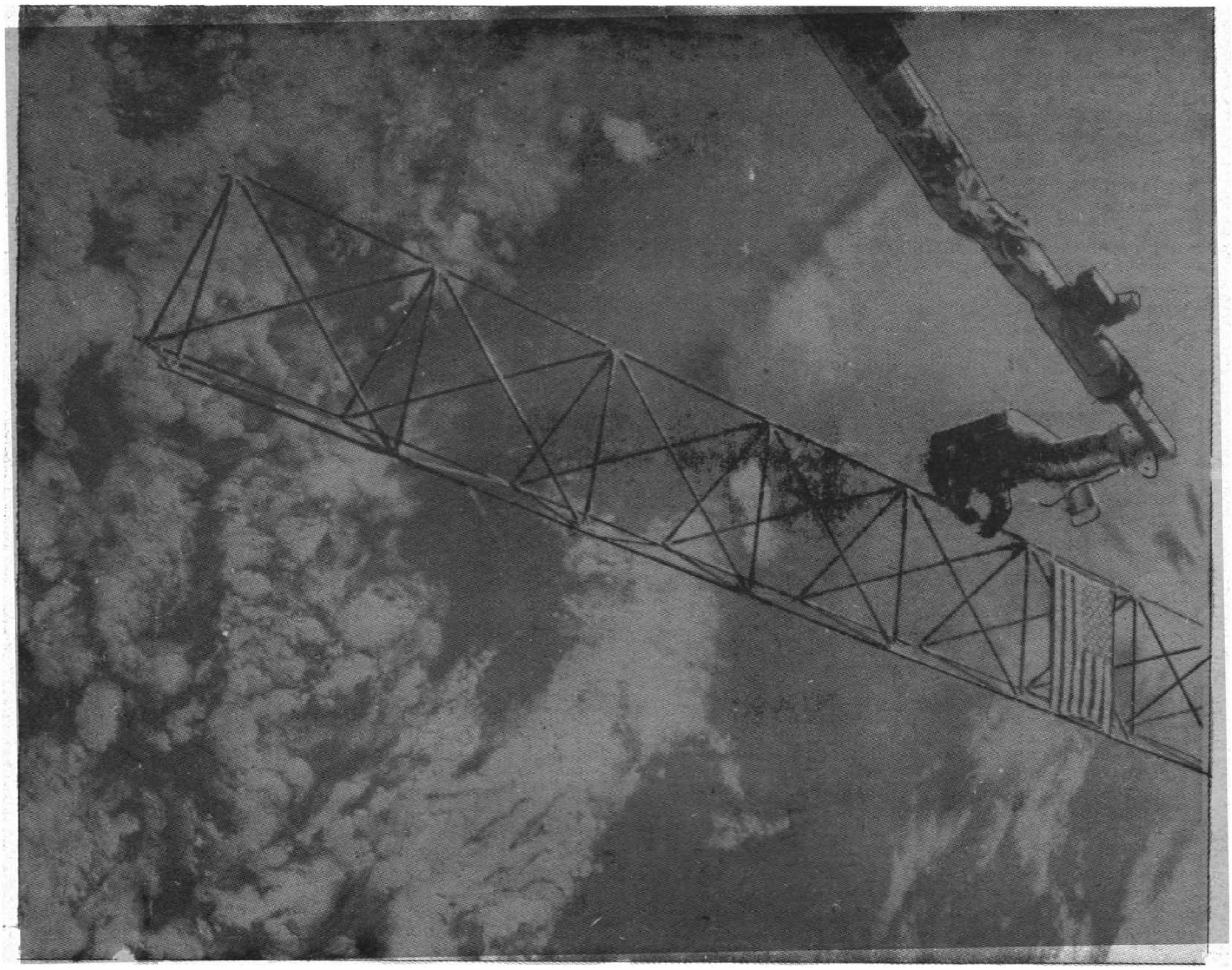
The aggregate of these tasks is a significant amount of work; but since each task is unique, it precludes automation because the unit expense is not warranted. For planned and contingency servicing, extravehicular activity (EVA) is both efficient and cost effective. All of our studies indicate that manned servicing is the strategy of choice when a high-value, unique system, such as one of the great observatories, is assessed over a long operational life.

When an operational system that must be maintained for a long period is considered, continuous servicing is more effective than replacement production. The net effect is a significant demand for use of crew as uniquely programmable, intelligent sensors and manipulators for performing such tasks of maintenance and refurbishment.

This kind of function in recent flights has been demonstrated in the solar maximum spacecraft repair and the recovery of the Westar and Palapa spacecraft. The crewman not only replaced a planned module interchange, but effected an unplanned wiring change. During the Palapa Westar recovery, the adapter to provide for remote manipulator system (RMS) positioning of the spacecraft would not fit due to a disparity between the original design and the final construction. Joe Allen held the spacecraft while all the entry tiedowns were attached.

We have also done some construction experiments on-orbit. The objective of these tests was to determine the relative effectiveness of various assembly techniques. We discovered that hands-on EVA is five to ten times more efficient than using manipulators or teleoperators and that two different manual techniques were essentially

Joe Allen holds onto the top of the retrieved Westar after Dale Gardner captured and stabilised the communications satellite during mission 51A in November 1984.



The National Commission on Space illustrated a manned Mars outpost analagous to the Antarctica research stations as a suitable goal to illustrate its future exploration theme. This illustration is from the cover of the report.

equivalent. The crew handled over 500 units of untethered equipment without any escapes. We plan to use such assembly techniques in building up the Space Station in orbit.

Space Station Operations

The Space Station is NASA's next major project. In the past, each of our major projects has been a self-contained enterprise. Each programme had a specific mission objective and everything was focused to achieve that objective. The new generation of systems, the Shuttle and the Space Station are not designed for a single specific mission objective, but are designed to provide the capability to achieve many objectives over the next two decades. The Space Station and the Shuttle are complementary elements of a space operations infrastructure. The Shuttle provides transport from Earth to low-Earth orbit through the atmosphere; the Station provides a depot at low-Earth orbit for storage, assembly, and the execution of long-term operations. Upper stages provide transit to higher energy orbits. A candidate project after the Space Station will be a Space Station-based manned aerobraking reusable upper stage.

Missions that the Space Station can then support are manned sorties to geosynchronous orbit, the development of a lunar base, and a manned Mars mission. The use of the Station as an assembly point and depot provides new techniques for developing large systems in space without having to develop continually larger launch vehicles.

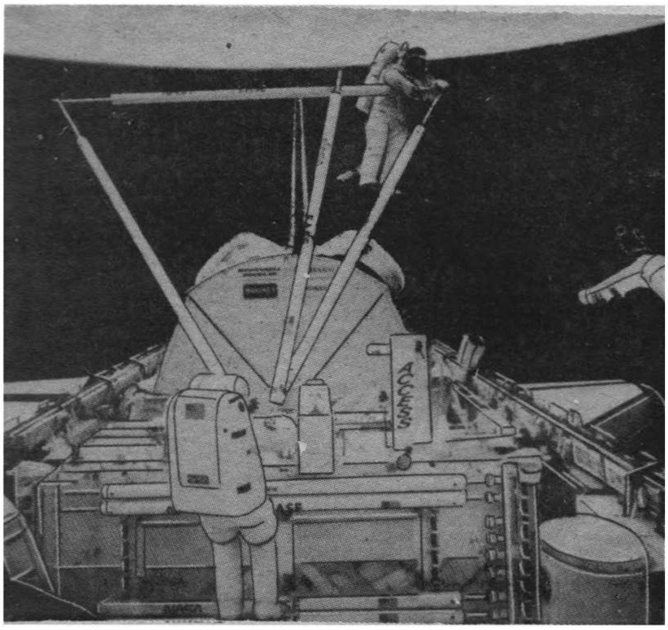
The pattern of activity we anticipate is that the Station will be used as a laboratory for prototyping manufacturing facilities for various classes of high value materials. We anticipate that once pilot plant scale is successfully demonstrated, the function will be transferred to a man-tended platform that will be serviced from the Station or by the Shuttle. Servicing would consist of replenishment of operational consumables, maintenance, harvesting of product and new feedstock.

In the initial bench-testing of devices and processes, we would expect a high degree of manned interaction with experimental apparatus. In pilot plant operations, we anticipate the normal experimentation with control variables to define scaling laws and process control laws so the automated plants can be developed. We would expect to monitor and control production plants on man-tended platforms from ground facilities in order to optimise the microgravity environment by minimising disturbance sources during production runs.

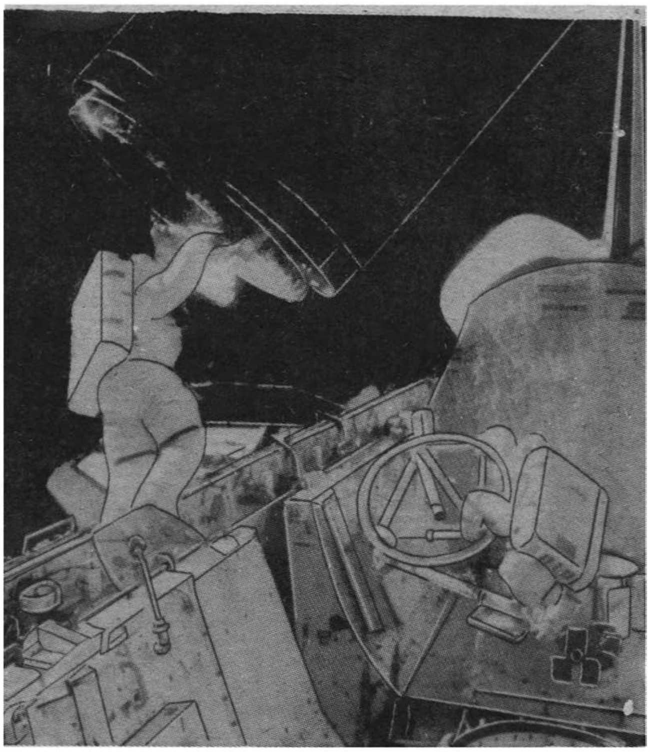
These activities will engage an entirely new class of space crews currently called payload specialists or mission specialists. In our Shuttle operations, payload specialists are user-supplied and are trained by NASA only in how to live and work in our spacecraft. Mission specialists are NASA crews – generally scientists or physicians who can act as surrogates for the user in operating experimental equipment, but who also do specialised tasks in EVA or manipulator system operations and assist the commander and pilot in flight vehicle operations.

In addition to laboratory activity, the Station will be a site for construction and assembly of systems too large or too heavy to launch as a single unit or which require attributes better achieved by assembly on-orbit. Some of these assembly tasks will be effected with manipulators using smart end effectors, e.g. force and torque sensing. The operation of such devices is quite intricate because of the complexity of the geometries involved and the need to manage the movement of both

Man's Role in Space

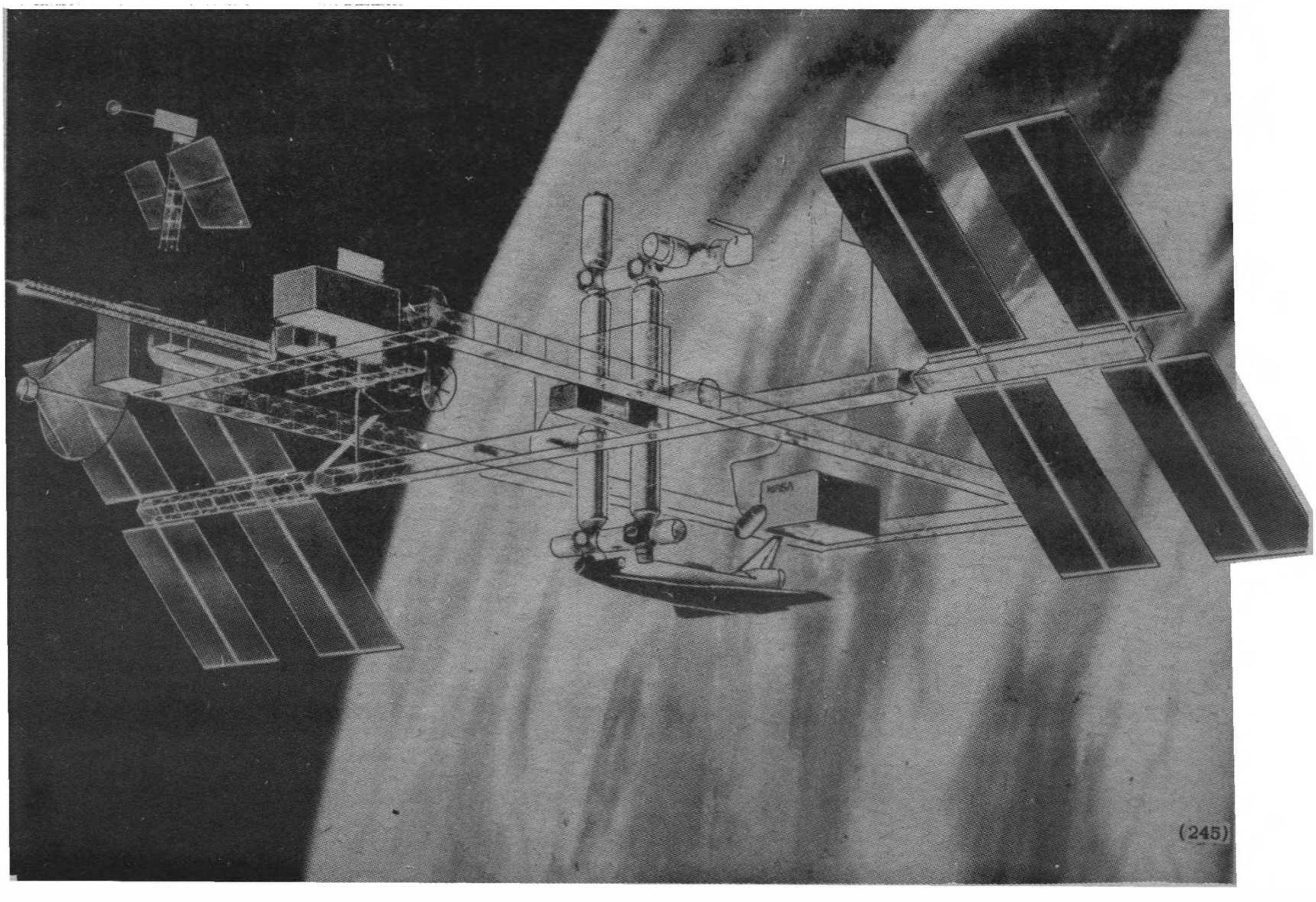


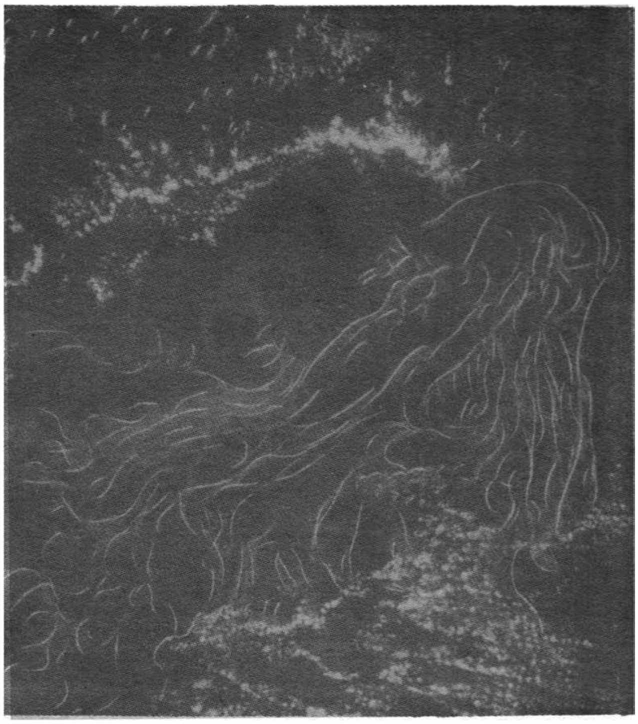
EASE is the Experimental Assembly of Structures in Extravehicular Activity. This experiment provides for the crewman to float free in space and manipulate himself and the assembly elements by conservation of momentum. On-orbit assembly times were equivalent to water immersion simulations at the end of training.



Two recovered spacecraft (Palapa B and Westar 2) would not accept the intermediate adapter intended to allow RMS positioning of the satellites while hold-down fittings were attached to the satellites base. A device adjusted after spin-test protruded into the envelope of the adapter and clearance tolerances were inadequate to the as-launched configuration. During mission sequence simulations, the alternative procedure of having the crew hold the satellites were developed and resorted to when the adapter could not be made to fit. Both spacecraft were recovered with essentially no damage – the highest value salvage operation in history.

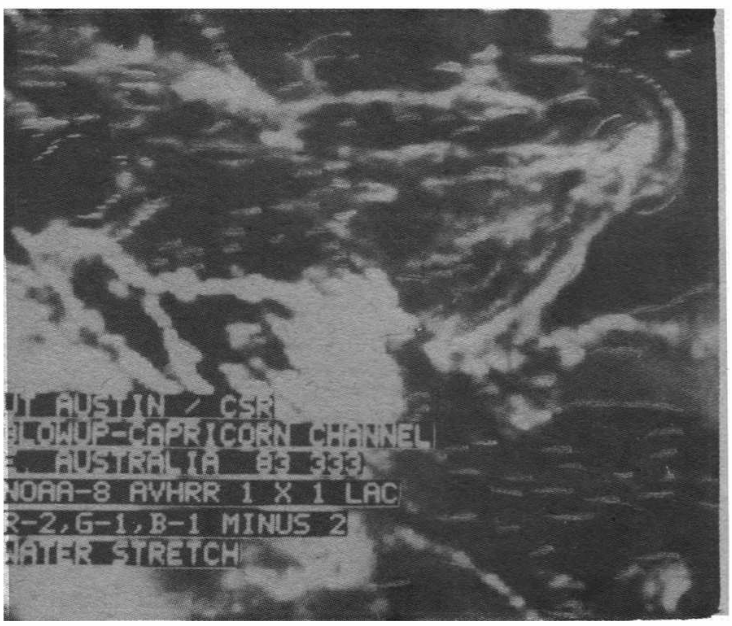
This drawing illustrates a reference design concept of the Space Station.





In this nadir view, as the Shuttle passed over the Capricorn Channel of the Great Barrier Reef east of Australia, the crew observed the formation of tendril material in the northeastern flow from the channel. Such a phenomenon had not previously been observed. After flight, it was determined to be a phyto-plankton bloom. On subsequent flights similar events in the North Atlantic and off the East African coast have been identified. These events are significant to the understanding of ocean currents, weather and commercial fishing. This is one of the 28,000 images from manned space flight photographs and is illustrative of observer-selected photographs.

To assess the phenomenon noted in the picture below imagery from the advanced very high resolution radiometer, an instrument flown on the NOAA-8 weather observing satellite (National Oceanic and Atmospheric Administration), was examined. This image was produced from two bands (of seven) most sensitive to blue-green wave lengths and confirmed the phenomenon as a phyto-plankton bloom. These comparative images illustrate the synergistic interaction of manned synoptic observation enhancing the data acquisition from automated spacecraft. Other examples can be cited in which crew observations have been and are being used to characterise or identify phenomena first detected by automated spacecraft. Such synergism facilitates the transition from data acquisition to information acquisition and illustrates the importance of both systems, manned and unmanned, as complements to each other.



the arm and the viewing systems. Our current approach is to use manual controllers for translation and attitude control of the manipulator members and to develop voice commands to manipulate camera selection, pan, tilt, zoom, and focus. The use of voice command significantly improves rapidity of operations and, therefore productivity.

There will always be activities which require EVA for direct crew manipulation of devices. The design of the EVA equipment for such operations offers a significant challenge in providing crews with efficient life support enclosures that require minimum energy to manipulate, where display and controls for the operating systems are easy to use and where the task documentation and tools are readily accessible.

Manned or Unmanned

Our experience suggests that manned and unmanned systems are complementary. There have been numerous instances in the past 25 years in which we have detected phenomena during manned flights and later developed automated systems by which they could be monitored. We have also detected and identified phenomena on manned missions which had been latent in the imagery from unmanned operational systems; but because it was unanticipated, it was never recognised. The human sensory and cognitive system makes people extraordinarily efficient difference detectors. It is anticipated that manned and unmanned systems will continue to be complementary. Continuous and routine operations are obviously best done by automated spacecraft, but synoptic viewing by crews will continue to detect and identify phenomena of both instantaneous and long-term significance. Eventually, such experience may be codified into automated observing systems that send information to the ground, rather than extended streams of raw data which subsequently require extensive synthesis and analysis.

For the past 27 years, an ever increasing torrent of data has come back from space – all of which cannot and probably should not be examined. However, buried in the torrent, are gems of great value if we had the wit and skill to recognise them. Complementary operation of manned and unmanned observing will be needed in order to distinguish information from data.

In many discussions of manned space systems, the question is raised, "Why not use unmanned automated systems?" This is not an either-or question, and it is basically mis-stated.

All systems are manned, for only man acts with purpose. The question is one of man's proximity, in place and in time, to the activity. In the limit, man is present only at the design and man-

The National Commission on Space illustrated a manned Mars outpost analagous to the Antarctica research stations as a suitable goal to illustrate its future exploration theme. This illustration is from the cover of the report. *Robert McCall*

ufacturing for the untended automaton. We have no such system in space and few on Earth. In managed, automated systems, operators constantly or intermittently participate in maintaining or modifying systems, but physical proximity is not required. In man-tended systems, periodic *in situ* presence is required. In manned systems, man's presence in continuous; but his participation in any given activity is often intermittent or only required if automated systems fail or prove to be inappropriate to the context of the situation.

Simple deterministic tasks can be automated and should be. Some tasks which depend upon contingent decisions can be automated when the designer has expert knowledge of both the system and the contingencies which will require choice. A dilemma arises as one rarely has, especially in large, complex, newly designed systems, either expert knowledge of the components or subsystems that comprise the system, nor a complete and comprehensive knowledge of all the operations the system will be called upon to perform. The effect is to make manned inclusion desirable because skilled crew are so easy to "programme" compared to any available alternative. This is really the most significant point – people are so much easier to programme or reprogramme than any system of comparable capability. The more highly skilled the people are, the easier the reprogramming; much of which can be done by the crew itself in real time.

Unmanned systems, man-tended systems, and varying levels and types of automation in manned systems will be used to conduct operations in space efficiently, effectively and safely. There are significant challenges in enhancing the interface between men and machine in all of these contexts. The challenge for men in space exploration and exploitation in the future is as great as it has ever been in the past.

The Space Future

The National Commission on Space reported to President Reagan on July 21, 1986 and to the Congress on July 22 the results of their one-year deliberation of future roles of the US space programme. The Commission advocated three themes that the nation should pursue: science, exploration, and commercial enterprise.

A long-term goal that the Commission advocates is a manned outpost on Mars. Such a proposal may seem unreasonably bold, but as an objective 40 years away, it may be modest. Keep in mind that the first flight of the Shuttle came within in one month less than 25 years after the flight of Yuri Gagarin, the first manned orbital flight. Within that span of 25 years, the United States has landed men on the Moon, operated its first Skylab Space Station, and developed the Shuttle. The USSR has developed a family of manned and unmanned vehicles to service and support its Salyut and Mir Space Stations. In such a context, a Mars outpost 40 years from now does not seem unreasonable.

The near-term charge that the Commission has made to the President and Congress is that the nation needs to immediately embark upon a significant increase in its technology development and advanced mission studies. The Commission expressed great concern that the progress in flight programmes in the past 15 years has been based on a technological and human resource base built in the 1950's and 1960's and that the resource had not been replenished.

Therefore, the Commission has recommended a 300 per cent increase in technology and advanced mission studies. NASA has responded with a Civil Space Technology Initiative in order to begin restoration of the technology base.

The Commission's vision is a challenge which may be difficult to respond to at a time when we are constituting our ability to launch and are still endeavouring to define the Space Station. The best guidepost for a constant course is always on a far horizon.

REFERENCES

1 Garman J, "Forecasting trend in NASA flight software tools," 83-2334 Proceedings. *AIAA Computers in Aerospace IV Conference*, New York AIAA, 1983; AIAA CP 837

2 Loftus J P., Jr., "An Historical Overview of NASA Manned Spacecraft and Their Crew Stations," *International Centre for Transportation Studies Aerospace Crew Stations Design*. In: Carr G.P., Montemerlo, M D., eds, New York: Elsevier Science Publishers, 1984.

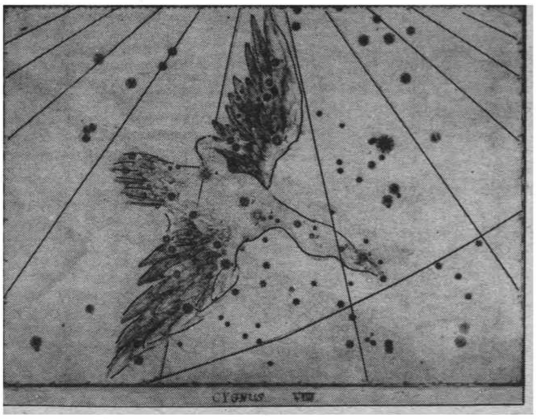
3. Sheridan T.B., "Supervisory Control of Remote Manipulators, Vehicles and Dynamic Processes," In: Rouse W B., ed *Advances in Man-Machine Research*, New York: JAI Press, 1984-49-137.

An Opportunity to Share in a Part of Astronomical History

Johannes Bayer (1572-1625), the author of Uranometria was a Bavarian lawyer. This drawing is taken from a rare portrait of him in the late 16th century.

SIX STAR MAPS

Reproductions of Constellations



- The constellations reproduced are Bootes, Hercules, Cygnus, Auriga, Pegasus and Argo.
- Each of the six pictures is printed in sepia on antique type paper to preserve the original characteristics of the Bayer Atlas.
- The prints are suitable for wall display, framing and preservation as collectors' items, or would make quite unique presents. They provide faithful actual-size reproductions of the original pages with titles added underneath in large typeface for display purposes. Size: 507 mm x 400 mm, including a 60 mm surround.

PRICE: for one set of SIX Star Maps (inclusive of postage and packing) £20.00 ($35.00).

From the 1603 Edition of Bayer's *Uranometria*

The Uranometria (Atlas of the Heavens) first appeared in the year 1603 and continued as a major work of reference throughout the 17th and 18th centuries.

It consists of 51 copper-engraved star maps recording the approximate positions and magnitudes of some 500 stars observed by Bayer himself, in addition to those that had formed the renowned catalogue of the Danish astronomer, Tycho Brahe, only a year earlier. While adopting the magnitudes and positions of Tycho's stars, it gave – for the new stars – the magnitudes that Bayer had recorded himself. He also adopted a system of notation of brightness, based on the Greek Alphabet, viz: alpha, beta, gamma, etc, for the six orders of magnitude handed down from antiquity. Bayer identified 1706 constellation stars of these magnitudes, plus 325 that are not in clearly identifiable constellations.

To: The British Interplanetary Society,
27/29 South Lambeth Road, London, SW8 1SZ, England.

Please find enclosed a remittance of ....for ....set(s) of SIX Bayer Star Maps at £20.00 ($35.00) per set for immediate despatch to:

NAME ______________________________

ADDRESS ______________________________

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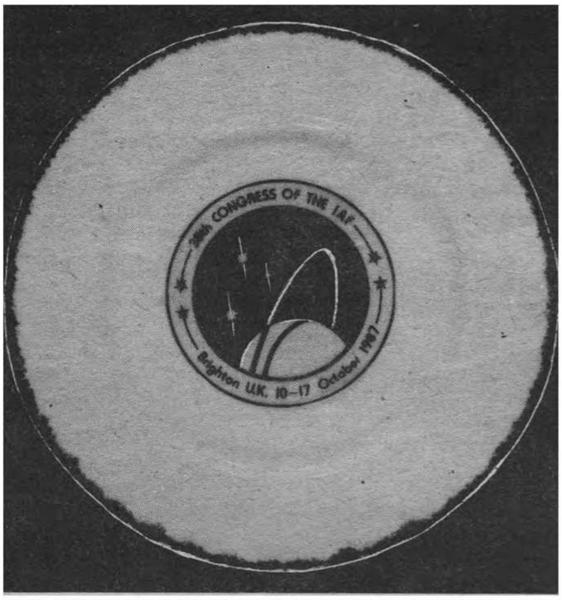
These items are available as part of our fund-raising programme in support of the new extension to the Society's HQ premises.

Please Photocopy



- Eight inch Fluted Bone China Plate with Gold Edging and Congress Logo in Blue.
- This plate is a fine example of English bone china by Goss, which is a part of Royal Doulton specialising in commemorative china.
- An exclusive edition of 600 plates (un-numbered) has been commissioned and production will be strictly limited to this total number.
- The plate will be available from October 12, 1987 which is the Opening Day of the Congress.
- To ensure delivery to your UK or overseas address directly after October 12, 1987, please order now enclosing the appropriate remittance.

PRICE (inclusive of postage and packing): £11.00 (to UK); £12.00 or $20.00 (overseas).

– a lasting momento of a major event of international astronautics.

COMMEMORATIVE

8 inch fluted china

PLATE

In honour of the 38th Congress of the International Astronautical Federation (IAF) to be held in Brighton, UK from October 10-17, 1987, the British Interplanetary Society has commissioned the production of a special commemorative plate bearing the Congress logo.

IAF Congresses have been held annually since 1951 in Europe, Asia and America and represent a major activity of peaceful international space cooperation. The total IAF membership now runs to 80 organisations from 40 countries. It includes many leading industrial organisations and represents a vast range of talent among engineers, physicists, physiologists, educators, executives and other professionals concerned with astronautics.

The British Interplanetary Society was a Founder-Member of the IAF and hosts the 1987 Congress in the United Kingdom.

To: The British Interplanetary Society,
27/29 South Lambeth Road, London, SW8 1SZ, England.

Please accept my order for ....38th IAF Congress **Commemorative Plate(s)** for postal delivery to the following address after October 12, 1987:

NAME ______________________________

ADDRESS ______________________________

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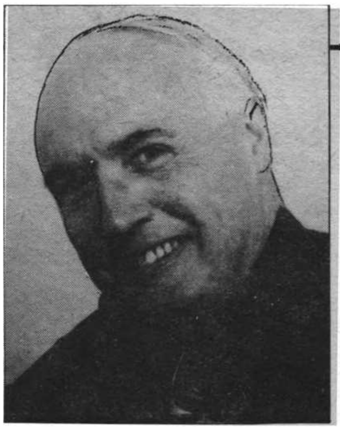
I enclose a remittance for £..................$.................(£11.00 UK: £12.00 or $20.00 overseas per plate inclusive of postage and packing).



Mr. Len Carter.

SPACE AWARD FOR SOCIETY

The 1987 Arthur C. Clarke Award for Space Education is to be made to the British Interplanetary Society with Mr. Len Carter, Executive Secretary, as the nominated personal recipient.

The announcement of the Award states that "since its founding over 50 years ago, the British Interplanetary Society has led the world in pioneering space educational publications and activities. The Arthur C. Clarke Award for 1987 is especially dedicated to honour Mr. Carter's talents and efforts as Executive Secretary of the BIS. It recognises his immeasurable role in creating and guiding the Society's outstanding programmes in space education."

The Award was created in 1983 to recognise outstanding personal and society contributions to space education and is administered annually by SEDS (Students for the Exploration and Development of Space) whose headquarters are at The Massachusetts Institute of Technology, Cambridge, USA.

In the tradition which has been established for the Award, Mr. Carter will be presenting the keynote address as the International Award Banquet of SEDS this summer when the Award will be made.

Past recipients of the Award are: Dr. David C. Webb (1983); Dr. Carl Sagan (1984); Dr. Philip Morrison (1985); and Dr. Gerard K. O'Neill (1986).

The following letter of congratulations has been received by Mr. Carter from Arthur C. Clarke.

Dear Len,
I was so delighted to hear that you and the BIS have just received the 1987 Arthur Clarke Award for Space Education.
I would like to add my congratulations to those of all the other people who have doubtless written to you!
I sincerely hope that you can go to the US to deliver the address in due course.

All good wishes,
ARTHUR

Special items available from the Society

TIES

Now in stock is the Society's dark blue tie with the traditional design of rocket and three stars in white. The price, inclusive of postage and packing, is £6.00 UK (abroad £6.50 or US$11.00) which has remained unchanged for some years.

The tie is a useful and unique item to possess. Newer members may not be aware of its availability and may like to take this opportunity to acquire this means of signifying their association with the Society.

Longer-standing members may like to consider a replacement for their previous, and probably by now much-worn ties. Just write to the Society with remittance enclosed and the tie will be despatched immediately.

COMMEMORATIVE PLATE

As announced opposite the Society has commissioned the production of an eight inch bone china plate to commemorate the holding of the forthcoming 38th IAF Congress in the UK.

Only a limited number of 600 plates will be available and members are advised to order as early as possible. Priced at £10.00 (plus postage and packing) the plates are expected to be a popular acquisition as a momento of this major international event. Orders will be despatched on the Opening Day of the Congress, October 12, 1987.

REPRODUCTION STAR MAPS

The publication of the Star Atlas of Bayer in 1603 was a landmark in the development of positional astronomy. The Society is fortunate to hold one of the remaining copies of this first edition, which members may recall was the subject of an earlier article in *Spaceflight* of March 1985 (p.117).

The individual star maps have an artistic quality in addition to their scientific merit and the Society has arranged for a selection of six of the maps to be reproduced to conform as closely as possible with their original presentation. Further details are provided in the announcement.

The reproductions are now available as a set of six for £20.00 inclusive of postage and packing. All proceeds from the sale of these items are being allocated to the Society's £80,000 Building Appeal. Members are urged to support the Appeal in this way and at the same time acquire these attractive representations of an important piece of astronomical history.

NASA VIDEO TAPES

The Society has acquired the exclusive UK distribution of an extensive set of NASA Video Tapes which has been prepared by Istead, the Birmingham-based communications technology specialists. Details of a selection of the set appear on the back inside cover of this issue. Orders should be sent to the Society from whom details about the full set of tapes is available on request.

FIRST CLASS MAIL

A speedier delivery of *Spaceflight* to UK members can be expected beginning with the next issue when despatch will be by First Class Mail.

Our apologies to any UK members who did not receive their May issue on time. This was due to the way in which the despatch was handled by our mailing agents and steps have been taken to ensure that a similar delay does not arise again.

It is intended that members should receive their copies of ***Spaceflight*** as early as possible and the introduction of First Class Mail is expected to bring a noticeable improvement.

ASTEROID NAMED

We are delighted to learn that BIS Fellow W.A. Bradfield of South Australia has been honoured by having asteroid 3430 named after him. The announcement was made recently in Minor Planet Circulars and we extend our congratulations to him on receiving this important recognition.

'More Space for SPACE'

The Society's Headquarters

As announced in our last issue, planning permission has been granted for a much needed extension to the Society's Headquarters. The yard at the rear of part of the property (No. 27) will be built upon to provide extra working space on the ground floor and to extend library and publications facilities on the floor above.

The Society has occupied its present premises for more than eight years during which time its work has greatly expanded in both scale and influence. It is now urgent that the proposed building work is started as soon as possible to provide 'More Space for SPACE'.

Contributions are urgently sought to the Society's £80,000 *Building Appeal Fund* and members, in particular, are urged to support this step in the Society's development. Please send whatever you feel able to contribute. This will be most gratefully received and acknowledged.

EXTRA ISSUES OF 'SPACEFLIGHT'

Arrangements are in hand for the publication of two supplementary issues of *Spaceflight* for the two months of the year (July and October) when the magazine would not otherwise appear.

These issues will be devoted to articles on a range of space topics and provide a valuable addition to the ten regular issues of ***Spaceflight*** which members normally receive. The extra supplements will also conveniently fit into the annual ***Spaceflight*** binders for these are designed to accommodate up to 12 issues.

Those members who have already remitted £4.00 (or US$6.00) for the two issues of *Space Education* in 1987 will now automatically receive the two supplementary issues of ***Spaceflight*** in lieu of *Space Education,* publication of which will be suspended, the last issue being Vol, 1. No. 12, dated Autumn/Winter 1986/7. Articles and reports relating to space education will now be re-allocated to the July or October ***Spaceflight*** supplements.

All other members can secure the July and October ***Spaceflight*** supplements by post by simply writing to the Society by June 15 and enclosing a remittance of £4.00 (US$6.00).

SHUTTLE TRIBUTE

BIS Fellow and space artist Ian Moule has received a letter from John Young, Chief of the Astronaut Office, about his Space Shuttle painting which now hangs in the Astronaut Office at the Johnson Space Center.

The picture was prompted by the Challenger disaster, when Ian was so moved by the tragedy that he painted the picture as a memorial and handed it over to astronaut Claude Nicollier at the *SPACE '86* conference in Brighton last year.

In his letter, John Young writes: "It was a thoughtful gesture to give this fine piece of work to the Astronaut Office where it is on display along with other tributes to the astronaut corps."

Young has now taken up a new appointment and his position taken by Daniel Brandenstein (see p.234)

The Headquarters of the Society

"Your generous support will help our building programme to go ahead without delay"

Charity Commission No 250556

Rex Turner, BIS President 1985/7

I have pleasure in enclosing a contribution* towards the Society's Building Appeal of £ $

I would like to receive a copy of the Society's Brochure *'Guide to Aims and Activities'* ☐

NAME ____________________

ADDRESS ____________________

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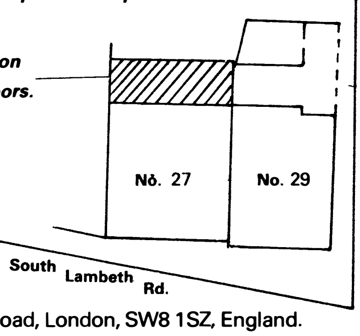
£80,000 is urgently required for an extension to the Society's premises to enable its operations and facilities to support today's increasing developments in space.

Proposed extension on two floors.



*Payments from UK may be made -

(a) By cash, postal order or cheque made payable to 'BIS'

(b) By GIRO Our GIRO account number is 53330 4008

Payments from abroad may be remitted as follows -

*(a) From Europe the easiest way is by GIRO transfer

(b) By Eurocheque with the account number written on the reverse side

(c) By US dollar cheque drawn on a Bank with an address in the USA

(d) US dollar notes

(e) Members may instruct their Banks to remit directly to the Society

(f) US or Canadian money orders payable in Sterling

Send to: The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

MEETINGS DIARY

Society meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

6 June 1987, 10 am – 5 pm — Symposium

SOVIET ASTRONAUTICS

Offers of papers are invited. Society members with a special interest in the Soviet Space Programme are invited to attend the symposium to be held at the BIS HQ, London. A registration fee of £5.00 (members), £7.00 (non-members) is payable. Forms are available from the Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose a stamped addressed envelope.

19 September 1987, 12 noon — AGM

42nd ANNUAL GENERAL MEETING

The 42nd Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, September 19, 1987 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Fellows only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on June 26, 1987.

If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate members.

10-17 October 1987 — Congress

38th IAF CONGRESS

Invited lectures, Symposia and over 600 technical papers will be presented. To be held at Brighton, England, hosted by the British Interplanetary Society. To go on the mailing list for free information send your name and address to: "38th IAF Congress", The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

13-15 October 1987 — Exhibition

SPACE '87

SPACE '87, an International Exhibition of Space Technology will be held jointly in Hall six of the Metropole Hotel, Brighton and in the nearby Brighton Centre. It is open to Society Members and Members of University or Polytechnic Departments on any of the above dates.

Admission tickets will be required for those who are not registered participants at the 38th IAF Congress which will be held concurrently at the same venues. Tickets may be obtained, free of charge, by applying to the Society enclosing a reply paid envelope. Each member of the Society is also entitled to bring one guest, in which event a second ticket should be requested.

15 October 1987

SPACE '87 – Education Day

Teachers wishing to arrange visits by school parties to ***SPACE '87*** on this date should contact the Society.

17 October 1987

Technical Visits Tours

The Society has arranged two all-day technical visits to take place on Saturday, October 17, 1987 as follows:

Tour 1: The National Remote Sensing Centre, Farnborough and the Meteorological Office, Bracknell.

Tour 2: The Rutherford Appleton Laboratory, Didcot and the UKAEA Culham Laboratory.

Each Tour includes the provision of luncheon and transport by private coach to and from Brighton, with a stop on the return journey at Victoria Station for those wishing to disembark in London. The Tours may be joined either at Brighton or at the first organisation visited.

Members of the Society can apply for a place on either of these visits by writing to the Society enclosing the appropriate fee: (Tour 1, £22.50; Tour 2, £17.50). Members who will be attending the 38th IAF Congress should apply on the Congress Registration Form, copies of which are available from the Society. Further details appeared in ***Spaceflight***, April 1987, p.168.

4 November 1987, 7-9 pm — Lecture

FUTURE OPPORTUNITIES FOR EXPLORING MARS

Gary Hunt

It is more than a decade since the Viking spacecraft made their dramatic landings on the surface of Mars. Although our knowledge of the planet and the moons Phobos and Deimos has naturally increased, in some cases the information obtained has left us confused. The question of the possibility of past life on Mars and the possible effects of the variable climate of the planet are still strongly debated. Now Mars has once more become a major element of the planetary space programmes for NASA and the USSR. In this talk, we will discuss these future missions, which in the next few years include the Soviet mission to Phobos, the NASA Geochemical and Climate Orbiter, and the prospects for a Mars soil return mission and manned flight to the Red Planet.

Admission to members only. Please apply for ticket in good time enclosing SAE.

CORRESPONDENCE

Soviet Science Module

Sir, Dietrich Haeseler is to be congratulated on the accuracy of his analysis in "Design Features of the Mir Space Station", (***Spaceflight***, Nov. 1986, p.384). Despite my scepticism, the new Kvant module has indeed docked at the rear end of Mir, where it seems likely to stay. It has also been provided with a docking port so that Soyuz TM or Progress craft can be docked. I shall wait with interest to see whether Mir can be refuelled in this position and whether it can be used to adjust the orbit of the complex. Presumably future modules will dock at the front axial port then transfer to a lateral port.

Furthermore, the Soviets have clarified the design of Kvant's interior (***Spaceflight***, May, 1987, p.184 and this issue, p.236). It is now clear that the main laboratory bay is pressurised and that the crew will be spending a large part of their work time inside this bay.

The official statistics released are rather curious. Overall length of Mir-Soyuz TM2-Kvant was given as 35 m, and overall mass as 51 tonnes (t). Length of the laboratory module was said to be 5.8 m and mass 11 t, while overall mass of Kvant, including service unit was 20.6 t. Using the accepted figures for Mir (13.5 m long), and Soyuz TM (7 m long, 7 t mass) this gives a length for Kvant's service module of 8.7 m and a combined length for Kvant of 14.5 m – equal to Salyut 7 and longer than Mir itself. It also gives a mass of 9.6 t for the Kvant service module and 23.4 t for Mir, rather larger than the 20 t which is usually quoted (see table). Perhaps the official figures include the large amount of scientific equipment brought to Mir since its launch?

	Mir	*Kvant SM*	*Kvant LM*	*Soyuz TM*	*Total*
Length (m)	**13.5**	**8.7**	**5.8**	**7**	**35**
Mass (t)	**23.4?**	**9.6**	**11.0**	**7**	**51**

PETER R. BOND
Sheffield, England

Human Error

Sir, Following the letter by T. Devereux (***Spaceflight***, April 1987, p.170) regarding an anti-moonshot article in the Daily Telegraph, the first sentence of the quoted paragraph suggests the writer is anti-scientific anyway. There is no 'human race' – there are races (plural) of humans.

A.S. PAULIN
Romford, England

Apollo Politics

Sir, I respond to Tony Devereux's letter (***Spaceflight***, April 1987, p.170) to reassure him that the vast majority of people appreciate the benefits and capabilities that space exploration has brought.

Christopher Booker (Daily Telegraph, Saturday, February 28, 1987) may, indeed, be a part of that minority of people who believe that space exploration/exploitation is a waste of time, money and resources, but such a minority simply cannot influence a major change in public opinion. Let us then try to convince Mr. Booker of the usefulness and necessity of space exploitation.

In 1957, the United States was not only stunned but humiliated by the Soviet launch of Sputnik 1, and to make things worse, its own first satellite launch attempts failed miserably. Even after the launch of Explorer 1, US satellites (although doing great work, e.g. the discovery of the Van Allen radiation zones) appeared rather feeble in comparison to the size of the Soviet satellites.

With the massive publicity surrounding Project Mercury, everyone was convinced the United States would be the first to put a man in space. But once again they were humiliated by Vostok 1 and Yuri Gagarin. The United States and President Kennedy felt that national prestige had to be restored to the country's civilian space programme and the Apollo Moon Programme was embarked upon. Additionally, Apollo provided the necessary impetus for an intensive exploration of the lunar environment; hence the Ranger, Surveyor and Orbiter probes.

But Apollo could not provide the basis for a long-term national civilian space programme. Apollo was a one-off, short-term, prestige-gathering exercise which provided the opportunity to conduct intensive scientific exploration of the Moon and helped advance the technologies for future space programmes. It has no real bearing on today's programmes and is therefore not a good example to cite when debating the pros and cons of space flight.

So to answer Mr. Booker; yes, Apollo was a 'dead-end' of a sort, but it certainly was not baffling – it was a necessity to bolster the national morale of the United States and what it achieved for mankind was the exploration of the lunar environment. It helped formulate techniques in advanced computing, it advanced the theories and dynamics of structures and materials, it helped us advance physiological and biological knowledge by enabling us to study the adaptations of the human body and other organisms to the abnormal conditions of weightlessness – in short Apollo has played its part in the massive expansion in human knowledge and understanding, and in this way it did, in fact, "bring us closer to some ultimate truth" or to a "greater sense of humanity".

EDWARD R. LYONS
Manchester, England

The Solar System of 1846

Sir, I would like to donate the enclosed book to the Society's historical collection in the hope that you may find it of interest. It is *The Solar System* by Thomas Dick LL.D. and published, perhaps somewhat incongruously by present outlooks, by the Religious Tract Society of London. The influence of its sponsors shows clearly throughout. While maintaining a very high degree of scientific accuracy by the standards of its day, no opportunity is lost to glorify the handiwork of a supreme Creator manifest at every turn in the intricate mechanics of the universe.

The volume belonged to my grandfather and came to me through the estate of my grandmother. There is no date of publication printed on the flysheet, but a fairly accurate guess can be made from an examination of the astronomical knowledge displayed within: as an obvious example, the planet Neptune (identified towards the end of 1846) is not mentioned. The best clue to the date, though, lies on page 27 of part two where the discovery of an asteroid ("Astraea") on December 8, 1845 is described as being "within the last four to five months". The date can therefore be ascribed to 1846, between March (page 100, part two, describes the appearance of Gambart's Comet in that month) and about October (Neptune was identified near the end of September). The style of dress of the gentleman astronomer depticted in the frontispiece accords with this period, and on pages 191-2, part two, the author cites such illustrious names as Herschel, Airy and Earl Rosse amongst others, as being "in the present day .. distinguished cultivators of the science of the heavens", the Herschel being Sir J. Herschel, son of Sir William the discoverer of Uranus (page 190, part two refers.)

Many other fascinating glimpses of the prevalent scientific outlook of the early Victorian period are to be found in the text, an outlook in turn both whimsically quaint and piercingly shrewd. Page 175, part one, is headed "Lunar Inhabitants" and describes the sighting during the eclipse of 1836 of

a "distinctly perceived" atmosphere around the Moon! There is "little doubt", the author states, that the Moon "is a world replenished with inhabitants": the basis for this line of reasoning being the irrefutable fact that it would be "highly improbable that the Creator would leave a globe containing a surface of fifteen millions of square miles altogether destitute of sensitive and intellectual beings..." Mercury also is described as – "we can scarcely doubt" – the home of possibly "a population larger than even that of our globe" (page 100, part one). Jupiter is assumed the abode of life (page 49, part two) with a population who observe the interplay of the Jovian moons to "exhibit many curious and sublime phenomena to its inhabitants", and which "must be highly interesting and gratifying to the astronomers ... in that far distant world." The very rings of Saturn must exist to "form a habitation for numerous orders of intellectual beings ... it is highly improbable ... that such a space should remain for ever as a barren desert without contributing to ... intellectual enjoyment." (page 70, part two). Uranus is also a life-supporting planet (page 77), with beings whose eyes "may be so constructed as to take in ten or twenty times the quantity of light which our eyes would receive". (And this some 13 years before publication of Darwin's "Origin of Species" and the natural selection theory in 1859.) Even comets (page 104, part two) "are intended as habitations for various orders of intellectual beings ... adapted to the nature ... of the world in which they are placed." Mountains observed on Venus and oceans of water on Mars also make an appearance.

The "Explanation Of Terms" at the end of the book also provides food for thought, with a number of essential words which have now passed out of common scientific usage: Almicanters (lines of celestial altitude): Amphiscii (inhabitants of the torrid zone whose shadows point south one part of the year and north another): Antoeci (those who live on one meridian but at equal distances either side of the equator): Heteroscii (the inhabitants of the temperate zones whose shadows revolve for six months): Syzigy (the moon at opposition, conjunction or new or full).

The book also contains, of course, much that is accurate and clever, such as the conclusion that light moves, and at a speed of "about one hundred and ninety two thousand miles every second" based on time differences observed during eclipses of Jupiter's satellites at Earth's closest and furthest approach, which yielded a difference of 16 and a half minutes for light to cross the Earth's orbit, which for 1846 and prior is remarkably close to our present value for c.

It is all too easy when in a position of hindsight to smile at the notions of the past. Perhaps the greatest value of a book such as this to readers of the present, apart from allowing us a rare peek at the juvenescence of our science, is to encourage us to take a longer view of our own cherished and comfortable beliefs and prejudices and imagine, if we can, how those of 140 years in our own future might delight in the examination and dissection of our own writings!

PETER W. MILLS
Kent

Ed. *The Society gratefully acknowledges the donation of this book to its historical collection.*

Only Four Orbiters

Sir, In order to fulfill the absolute minimum requirements in manned space flight the US needs four Space Shuttle orbiters. This number could allow both NASA and the Pentagon to perform maybe 14 flights per year (Richard Truly estimated only 12 per year as a probable figure). This basic flight rate enables the US to perform some military missions plus launches required for erecting and maintaining a basic version of the space station.

However, this estimate does not account for two very important aspects. First: it neglects any increase in manned space flight activities beyond that already planned within the next two decades. And second: going into space is a dangerous business. One of the orbiters could be lost at any time.

Unrealistically, it is assumed that everything goes well until around the year 2005 when the "Orient Express" begins its test flights and is possibly ready for business some five years later. The estimate, therefore covers not less than 20 years of Space Shuttle flight service without any further accidents.

But let's face the facts: the Space Shuttle is a highly complex vehicle. Launch and landing will always be times of high risk.

I believe in manned space flight and I am convinced that it is worth the risk. But one must not be an extreme pessimist to consider a serious accident likely in over two decades of operation. What does the US intend to do in such a case? What is the "fall back" position – abandon the space station? Retain the remaining shuttles for military high priority missions? Abandon all manned fights?

One suggestion for a realistic Shuttle fleet could be:

1990: Fourth Orbiter as Challenger replacement. Delivery brought forward because of the growing payload backlog.
1993: Fifth Orbiter as originally planned by NASA, mainly as a circulation reserve.
1996: Sixth Orbiter as mission rates increase with the start of space station flights.
1999: Seventh Orbiter for Space Station expansion, especially because of increased crew size and transport of processed materials from the Station to Earth.
2002: Eighth Orbiter as the first replacement within the fleet (probably replaces "Columbia").
2005: Ninth and last Orbiter as second replacement.

This timetable assumes:

1. That the Aerospace plane is able to support normal US space mission requirements in its test flight phase, lasting at least until 2010.
2. That not more than one Orbiter is an irreparable loss within this time.
3. That the rate of manned space flight activities does not more than double within the next two decades.

Finally, I have included the following estimate of the number of persons permanently in space up to the year 2000.

Year	USSR	USA
1987	2–5	0
1990	6–8	0
1993	12–15	0
1996	20–30	2–4
2000	30–50	4–6

EUGENE K. REICHL
Rosenheim, W.Germany

Australia Turns to Space

Sir, I have noticed that Australia does not often get a mention in ***Spaceflight***, and no doubt that is because we, sadly, allowed our involvement in space projects to decline since the sixties.

Fortunately, that state of affairs is beginning to change, and one encouraging sign of the change is the Queensland Government's proposal to establish an international spaceport in Cape York.

JANE L. BROOKS
South Australia

CORRESPONDENCE

Quality Control

Quality control is without doubt an important matter. Technological progess depends on it. When everything works as it should, the role played by quality control is easily overlooked and other forces begin to gain an upper hand in the decision-making process. That is until some major technological disaster occurs, when questions are asked and the spotlight again falls on quality control. Bruce Remsbery, *who was formerly Metrology Manager at TRW Systems, a major US government contractor, offers this 'tongue-in-cheek' challenge to industry.*

Sir, The nuclear disaster at Chernobyl highlighted concern in the minds of many professionals as to our real appreciation and understanding of total quality control in a variety of projects not necessarily those confined to nuclear reactors.

Judging from personal experience, it seems reasonable to take the US aerospace industry as a standard example, particularly those parts of it with governmental and military programmes which are progressively monitored throughout their life cycle.

Quality involvement commences at the Design Review which looks at structural and other aspects from the safety angle. Once approved these go into the engineering drawing phase, where design checkers represent the quality element of that part of the project. If tooling is involved, this again goes through Design Review with fabrication planning written to include progressive quality inspections and an assurance that such checks are performed with currently calibrated instrumentation.

Detailed fabrication planning will again require an INSPECT action after each major step in the make process.

Final testing to ensure that a completed assembly meets all required engineering criteria is, in itself, a quality-oriented action.

Unfortunately, however, human nature being what it is, funding and time constraints may degrade what might otherwise have been a well engineered and quality controlled project.

The first indication of "corner-cutting" on quality usually occurs on commercial projects, where a budget-conscious project manager may rationalise that, as there is no governmental requirement for 100 per cent quality, they can get by with a watered down quality plan, and thus save some money.

Harrassed project office people have been heard to say how very much they are in favour of on-going quality assurance but nothing absolutely *nothing*, must come in the way of completion on schedule, so, "Gee-whiz, we're sorry!" The ultimate fiasco was the quality inspector who was actually threatened with physical violence by a contractor if he found anything to delay the project.

A good indication of how the quality team is viewed is sometimes found in the organisation chart where, for example, there are vice-Presidents heading up Personnel, Engineering and Manufacturing, but the Quality boss is a mere Director.

Above all, beware the organisation that shows the Quality Control element reporting to the Head of Manufacturing. Such an arrangement removes the essential ingredient of quality independence, and in the USA would be enough to delay the receipt of government contracts.

Where do we really stand on quality control in the UK? My impressions are perhaps sharper by having returned to England after a long period of absence.

My first quarrel was with the packaging business in general, and in particular with the people who incapsulate about 20 wood screws in a bombproof plastic bubble, welded to a piece of cardboard.

The US version has a perforated rear for easy extraction, but we are forced to stab in desperation with an ultimate loss of contents. Then there is that litre carton of fruit juice with instructions to cut along dotted lines. I have followed that instructions with the utmost of care only to get squirted in the eye! What ever happened at the Design Review on these items? In a fit of patriotism, I bought a new English car of well-known make and have had problems throughout and beyond the warrantee period.

Some recent experience with the UK aerospace business leads me to believe that they are committed to quality control. The sad part of this story however is that, in order to recruit qualified personnel, their search has been almost exclusively confined to the USA.

If UK manufacturers are hoping to benefit from sub-contracted portions of the Space Defence Initiative, they will probably be surveyed to determine among other things the level of existing quality and should be asking a good question ... where and how do we really stand on quality control?

BRUCE B. REMSBERY
Consulting Metrologist

When NASA Managed Hurricane Relief

Sir, Shortly after the first Lunar Landing in July 1969, Hurricane Camille struck the Gulf Coast of Mississippi. In spite of satellite monitoring, its exact landfall was not accurately predicted. Still, most of the impact area was evacuated and the death toll was minimised.

Camille was one of the most violent hurricanes ever to strike the mainland of the USA. It was one of the lowest atmospheric pressures ever recorded (26 inches of Hg), the highest winds ever recorded in a hurricane (220 kts, as measured by radar), and one of the highest tidal waves ever to hit the mainland (14 to 20 feet by various reports). The eye hit the Mississippi coast at Bay St. Louis and was a very concentrated eye. The damage was terrible. The final estimated cost of destruction was over $2 billion and the death toll was several hundred souls.

Normally, there are many Federal government agencies that move in to offer relief when great natural disasters occur. The Federal Emergency Management Agency offers direct relief funds. The Army Corps of Engineers finance rebuilding of roads, bridges, dams, etc. The Department of Education helps rebuild schools and sets up interim schools. And so on ... some 13 Agencies are involved.

As the damage was so widespread and complete, one of the Mississippi legislators got the idea if the relief funds were integrated, it might result with the whole being greater than the sum of the parts when the area was rebuilt. Further, if the rebuilding was "system engineered" with an overall master plan, it might be even better.

By coincidence, the NASA Mississippi Test Facility was located right in the heart of the devasted area. NASA had just completed the first lunar landing and the recognition of NASA's engineering prowess was the talk of the country.

The idea emerged of putting NASA in charge of all the Camille relief and let NASA "system engineer" the whole job. The idea was sold to President Nixon and he issued Executive Ordedr No. 49 which put NASA in charge of the relief with authority to integrate the relief expenditures. Unfortunately, NASA did not have "directive control", but only planning responsibility plus a form of "veto control". Still, this was enough power to provide the necessary leadership.

To implement the Executive Order, I was placed in charge of the effort and journeyed to Mississippi for a good share of the year 1970. We set up offices at the NASA Mississippi Test Facility as well as in Gulfport, Mississippi. A Task Force of NASA experts was collected and a Recovery Master Plan was developed using not only NASA expertise, but also local

talent, Mississippi State officials, and experts from other Federal Agencies.

All emergency actions such as flood clean-up, debris removal, emergency road and sea-wall repairs were carried out with dispatch and efficiency. New flood-proof building codes; flood-safe insurance programmes; improved flood damage-control facilities, sewers, tidal basins, etc. were readily accepted. However, when it came to other activities that would have a permanent impact on the socialogical and economic way of life it was a somewhat different story.

One example was the rebuilding of the several dozen schools that were destroyed. The schools were poorly located for the current population distribution and a suggestion to install a local television broadcasting system with receivers in the schools was put forth with the objective in mind of giving broader opportunity to the students. The locals rejected this concept (local counties control the schools in the USA) as it was felt that too much "outside influence" might be imposed on the local thinking. Similarly, the rerouting of major roads was considered in order to match the current needs. This, too, was greeted with local opposition. Officially, the argument was to 'preserve the local colour and nature'.

Still, the overall enterprise was extraordinarily successful in my opinion. A Gulf Coast Development Plan was produced which, though not strictly adhered to, formed the logical basis of the long term development of the area. Though, in general, the non-sequitur "If we can land a man on the Moon, we certainly can ... *(fill in)* ..." is more often wrong than right, I felt that in this case there was some merit in the analogy.

After the plan was published and placed in the hands of the local and State governments, NASA backed away from further effort in this area. I received an interesting set of orders from NASA Headquareters. "We want you to return to Washington to head-up another new activity. This is the development of a Post-Apollo Plan for cooperation with Europe, Canada and others on the Shuttle and Space Station Development."

Capt. ROBERT F. FREITAG
Former NASA Director
Policy and Plans Office
Office of Space Station

SETI

Sir, Bernard Oliver (***Spaceflight***, April 1987, p.171) thinks evolutionary biologists, like David Raup, are not opposed to SETI. Raup actually implies that aliens mimicking intelligence, though lacking it themselves, are more likely than the re-emergence of 'humanoid' intelligence[1].

Raup also implicitly recognises SETI's arbitrary splitting of the intelligence from the bodily aspects of the humanoid complex. Indeed, Oliver's question whether an octopus's descendants could fly spacecraft reflects such a division. The evolutionary objections to SETI concern this very point.

Evolutionary biology is not a predictive science. Influenced by chance variations, themselves unpredictable, the 'course' of any evolutionary pathway cannot be predicted[2]; and similarly for likely taxonomic groups. The possibilities are virtually unlimited! Clearly, alien 'phyla' will be radically different from anything we have ever imagined. The possibilities are far too vast to ever expect, as SETI does, that our humanoid pattern, however construed, could be duplicated elsewhere.

E.J. COFFEY
London

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IAF Congress Fees

Sir, I sympathise with Mr. R.W. Birch (***Spaceflight***, April 1987, p.167) over the fees for the IAF Congress. The IAF is intended for professionals in the field. Therefore the question of salaries and prices for those attending (whether from UK or overseas) hardly arises, since their fees and expenses will doubtlessly be paid by their employers. Retired people obviously do not get such concessions.

There are of course many conferences on many technical subjects for practising professionals, where the fees are far higher than those for the IAF Congress, but again the delegates to such conferences rarely, if ever, have to pay the fees themselves.

CHRISTOPHER ALLAN
Stoke-on-Trent, England

Building Appeal

Sir, Please accept the enclosed cheque as a donation towards the BIS Building Appeal and as a token of thanks for a long association.

WALLY HORWOOD
Surrey, England

Sir, Please find enclosed a cheque for the purpose of the new building programme recently announced. I am sorry that the amount cannot be greater, but circumstances dictate otherwise.

R.S. MacDONALD
West Lothian, Scotland

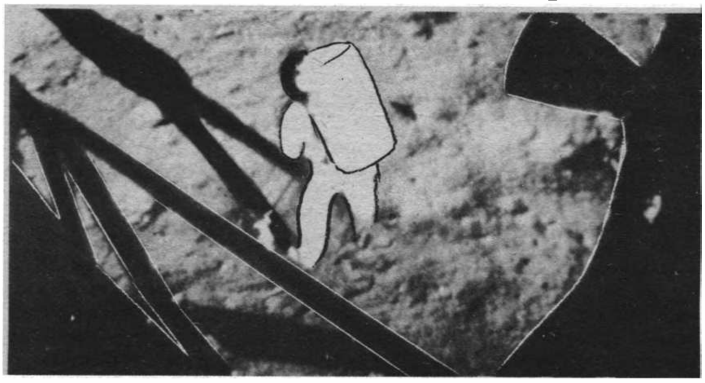
Ed. *Contributions to the BIS £80,000 Building Appeal are gratefully received and acknowledged. The Appeal is made to everyone interested in Space to support the Society's work of promoting Space and Astronautics by enabling it to expand its facilities and to have* **'More Space for SPACE'.**

Armstrong on the Moon

Sir, I have noted the recent correspondence in your columns concerning the existence, or otherwise, of photographs of Neil Armstrong on the lunar surface. The distinction has been made between TV images, automatic sequence camera shots etc and "real" photographs taken with a hand-held Hasselblad camera.

It may be of interest to recall that on page 40 of the January 1970 issue of ***Spaceflight*** there is a photograph of Armstrong on the Moon's surface taken by Aldrin from inside the LM. The quality of this picture seems to be consistent with the better-known photographs taken by Armstrong, and so may qualify as "real".

C.G. LEGGE
Bristol, England



CORRESPONDENCE

Wernher von Braun

March 23, 1987 was the 75th anniversary of the birth of the late Dr. Wernher von Braun in whose life's work are found the military origins of interplanetary flight with the development of the V-2 rocket in Germany and its peaceful realisation by the Apollo lunar programme of the USA.

Sir, Man's greatest trip so far, his journey to the Moon first undertaken in 1969, was mainly due to the vision of a German, Wernher von Braun, born in Pomerania in 1912 and working on rockets in the 1930's.

The tale really begins earlier – with the Treaty of Versailles in 1918 – when defeated Germany was forbidden to work on conventional weaponry, and therefore decided to work in secret on unconventional developments. It was at the age of 22 years that von Braun, who was then at Berlin University, transferred to a special armaments department under Walter Dornberger.

Wernher von Braun.

The development of Army rockets was well advanced by the mid 1930's when Hitler came to power and von Braun was already looking for a permanent test site. He chose Peenemünde, a quiet marshy backwater where he used to go duck shooting with his grandfather and where work began in 1936. The first demonstrations were made to Hitler in 1938, but he was not very impressed.

After innumerable failures and some 56,000 modifications, a practical rocket eventually materialised which was 14.3 m long, 1.5 m diameter with a range of 290 km and able to reach 97 km altitude at 1700 metres per second and a cost of about £12,000. But despite this achievement, Peenemünde was taken off the war priorities list. The first word of these rockets reached Oslo on October 17, 1939 and was relayed to Britain in early November. After some time Peenemünde was again given priority and the A4 (as it was then known) was fired for the first time on June 13, 1942, when it failed. This was followed by another failure in August, and it was only on the third firing in October that a success was recorded.

Hitler was angered by the raid on Lubek in the spring of 1942 and, although there had still been only one successful firing, mass production was decided on; meanwhile more information began to filter to England from Polish underground movements and Duncan Sandys was appointed to look into these 'rockets'.

1943 was an active year. The RAF had been photographing Peenemünde and a V2 was pictured there on June 12, and interpreted by Dr. R.V. Jones a few days later. Meanwhile, development work continued in Germany despite Hitler's doubts and mass production in three factories at Peenemünde, Friedrickshafen and Wiener Neustadt was planned. The V2 had its 38th failure the same month, but Hitler was reassured by a film of the only successful firing, shown to him by von Braun, then 31 years of age.

About this same time, the decision was taken to bomb Peenemünde, and the Americans were brought in as rumours were first heard of an 85 ton multi-stage rocket intended for bombing the USA. An attempt was made to knock Peenemünde out of the war on the night of August 17-18, 1943 when 433 bombers and 65 Pathfinders, amounting to nearly 4,000 men, flew out from stations all over the East Midlands and East Anglia. Known as "Operation Hydra" it was only a partial success, although greatly helped by a large diversion over Berlin by 139 Mosquito Squadron which drew the German night fighters away from the area.

The RAF lost 40 bombers and 290 of its highly trained air crew. Extensive damage was done to Peenemünde, and many people were killed, but nothing vital was destroyed that was beyond quick repair and none of the key personnel was eliminated.

A decision was then taken to disperse the work and deeper Poland was chosen for tests. Development work was to be done at Traunsee in Austria and the main factory was to be at Nordhausen in the Harz mountains, where a work camp – a satellite of Buchenwald called Dora with 13,000 inmates – was built, and the order given for 12,000 rockets at a rate of 900 a month.

The rockets were now being fired north eastwards from Blizna near Cracow, and some got as far as Sarnaki on the River Bug, where the Polish underground managed to steal one intact and dismantle it. Some intrepid Special Operations people flew a Dakota into the area from Brindisi and after several adventures brought out the parts in mid 1944, which eventually reached Britain. Blizna soon fell to the advancing Russians and tests were therefore resumed at Peenemünde, where a V2 flew to near Malmo and was captured and handed over to the Americans. Tests on the British one were carried out at Farnborough, but opinions remained rather complacent about its capabilities.

The SS then took over the rocket work, speeding things up to the point where there was an operational firing against Paris on September 6, 1944. London was attacked two days later on September 8. Two rockets were fired from The Hague at about 6.30 pm; one landed near Epping and did no damage, but the other came down in Stavely Road, Chiswick, behind the Hogarth roundabout, killing three people and wounding 17 others. No one quite knew what it was, or how to defend against it and initially it was reported as a burst gas main. Kammler, the new German Commander, attacked Antwerp and London again, where one landed on a Woolworth's store killing 160 people and causing a lot of other damage. Kammler managed to get production up from 24 rockets in September to 154 in November but the launching sites were finally overrun and the danger diminished.

The Germans fired the last two rockets on London on March 21, 1945, one landing in Stepney and killing 130 people and the other landing harmlessly in Orpington. Chaos soon reigned in Germany and by April von Braun and 500 of his chief experts left for Bavaria where a number of them surrendered to the Americans in early May, the same time that the Russians captured the remains of Peenemünde.

Von Braun and 127 engineers settled in America and soon began work on a multi-stage rocket for outer space. They started at Fort Bliss in Texas, but then moved to Alabama to build the Redstone rocket. Von Braun died in 1977.

There are four V2's preserved in England; one at the Imperial War Museum; and one at the Science Museum on display in the new Exploration of Space hall. The RAF Museum has one (in store) and there is the fourth in the RAF Aerospace Museum at Cosford. The Americans took about 100 V2's to the USA at the end of the War and fired off most of them, but one or two remain, notably in the Smithsonian Institution.

Peenemünde and Walten are in ruins, and as the last launching sites were from mobile bases, nothing remains of them. The galleries probably still survive at the Nordhausen underground factory, but it is behind the Iron Curtain and not accessible. I have not been able to find out anything about Blizna.

I appreciate that this letter is about past history, but I feel that the origins of space travel might interest younger readers.

PAUL TRITTON
Chelmsford, England

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Wernher von Braun *(continued)*

Sir, In answer to Mr. Devereux's reference (***Spaceflight***, April 1987, p.170) to the allegations made against Wernher von Braun, I assume that the reference was to the BBC TV presentation on Friday, February 20, 1987 of 'The Paperclip Conspiracy'. This programme, using documents recently declassified in the United States, recounted how Nazi rocketry and aviation scientists were taken across the Atlantic after being captured by the Americans in Bavaria in 1945 despite the available evidence that some of them had been involved in war crimes.

I will outline what the programme had to say with regard to von Braun.

In 1930 the German Army Weapons Office established a special unit to develop rockets under Captain (later General) Walter Dornberger. On August 1, 1932 Dornberger recruited von Braun and posted him to his 'Ballistics Office' in Berlin where, together with Walter Riedel, a liquid-oxygen engineer, he was provided with an experimental range at the Army proving ground Kummersdorf-West and given sufficient funds to experiment on rocket motors. In December 1935 von Braun visited his native Pomerania and selected the secluded Peenemünde area. In April 1936 the whole of the island's Northern Peninsula was purchased. Rocket test-stands were built along the eastern shore, where the Army's development of the A3 rocket (and later the A4/V2) could proceed without too great a concern for the provisions of security.

With the outbreak of war in 1939, the A4 programme was intensified and proceeded despite many failures and other setbacks and an initial apathy towards the project by Hitler. In August 1943, Peenemünde received a devastating bombing raid from the RAF. By this time Hitler wanted to launch a revenge offensive against Britain and the V2 (vengeance weapon number two) received his full backing. Production of the V2 was centred at the Mittelbau (Central Works) at Nordhausen, in the Harz mountains. The weapon finally became fully operational in September 1944 and was used to bombard London, Antwerp and other targets.

Essentially, what the 'Paperclip Conspiracy' claims is that von Braun was a Major in the SS; that many of his team were Nazis and SS Officers; that he agreed to Himmler's conscription of thousands of concentration camp inmates to dig the vast tunnels at Nordhausen which would accommodate the factory where the V2s would be assembled; and that at least 20,000 inmates died there of starvation, fatigue, illness and murder.

Von Braun admitted he knew what the conditions in Nordhausen were like. In an interview he said: "The working conditions there were absolutely horrible. I saw the Middle Works several times, once while these prisoners were blasting new tunnels, and it was really a hellish environment. I had never been in a mine before, but it was clearly worse than a mine."

In the last days of the war the Germans destroyed most of Nordhausen's incriminating documents. The few which survived prove the intimate relationship between von Braun and the SS. Minutes of a routine meeting in 1944 record the rocket team's demand that the SS should kidnap 1,800 engineers from France to work at Nordhausen; von Braun, who was present at the meeting, agreed.

So in short, despite ample evidence that Wernher von Braun was a Nazi, an SS officer and involved in war crimes he was nonetheless taken to the United States because of his technical expertise and helped develop the first American ICBMs and satellite launch vehicles, he was given American citizenship, his wartime record was (necessarily) swept under the carpet and he was proclaimed a national hero. But, while keeping these facts in mind, let us accept that he deserves to be remembered also for his genius and his major contributions to the American space programme.

EDWARD R. LYONS
Manchester, England

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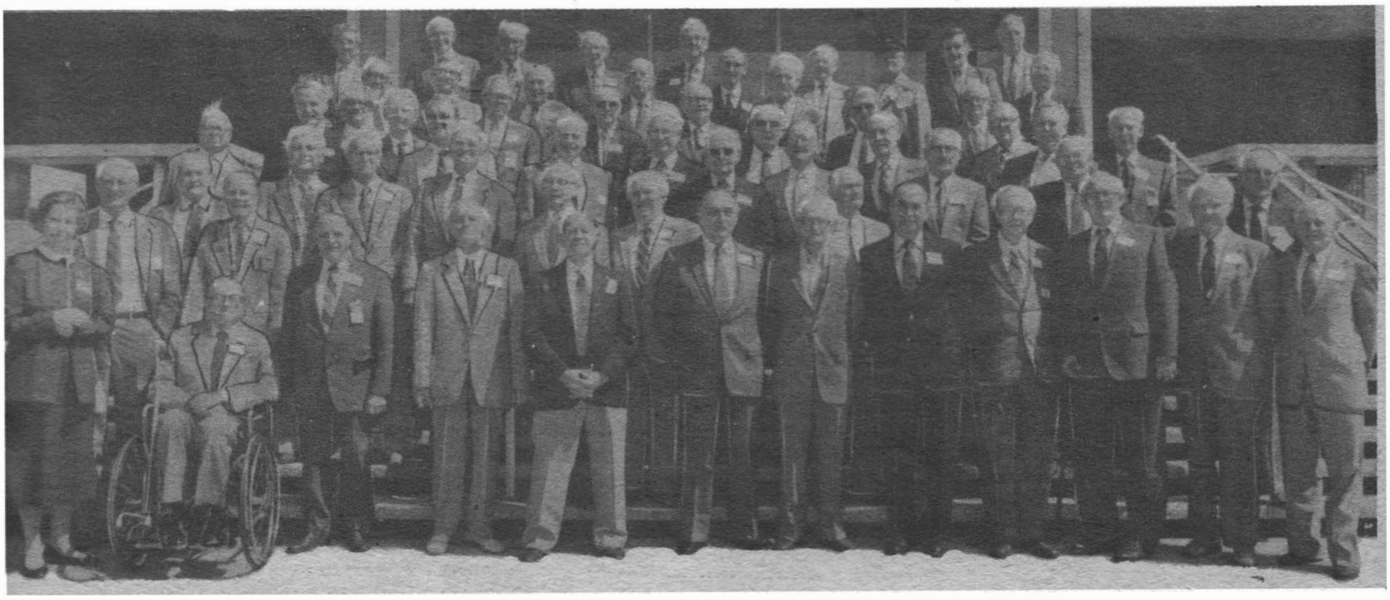


Peenemünde Team Visits Marshall Space Flight Centre

A renunion was held on March 23, 1987 the 75th birthday of the late Dr. Wernher von Braun, of members of the Peenemünde team of scientists and engineers who went to the US to work on rocket and space programmes after World War II. Of the group, only one member is still working at Marshall.

The Director of the Center, J.R. Thompson, said that the team deserved much of the credit for launching America's first ballistic missile, the nation's first satellite, putting men on the Moon and developing America's space transportation system.

"We recognise our obligation to you and to the memory of Dr. von Braun. Where you led, we now follow", he said.

Oceanography From Space

In December 1991, an Ariane 4 is scheduled to lift off from Kourou, French Guiana, to place an oceanographic satellite into orbit. The Topex/Poseidon mission is a joint effort between NASA and CNES, the French space agency, and is designed to provide an understanding of the global circulation of the oceans. The satellite will accomplish this objective by determining, through altimetry, the topography of the ocean surface – gentle hills of water – which reflects to a great extent the patterns of circulation.

The Ocean Topography Experiment (Topex) was initiated as a development flight project in January 1980 at JPL. In the same time frame, the French had been developing an ocean observational programme, Poseidon, based upon sensors to be placed on the Spot satellites. Discussions between NASA and CNES in 1983 led to the decision to conduct a study of the feasibility and desirability of a joint mission. At the completion of the study in May of 1984, the cooperative approach was recommended.

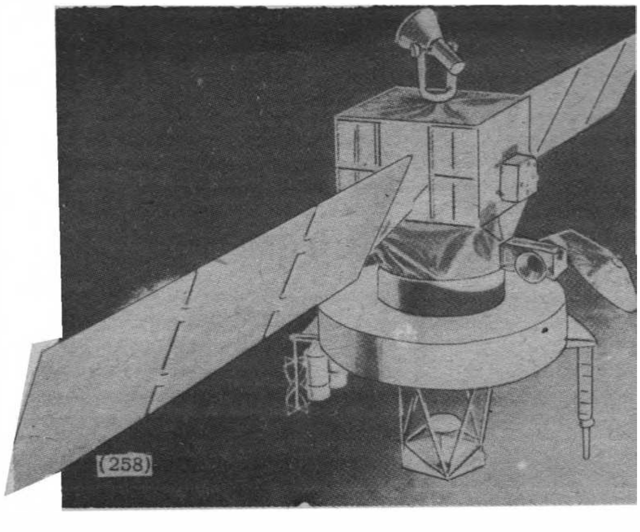
The US Topex project was submitted in the FY 1987 budget by the Administration and approved by Congress in November of 1986. French approval was forthcoming in February 1987 and a memorandum of understanding between the two governments was approved in March.

The scientific and economic potential of the mission can best be appreciated by reference to some of the major aspects of the ocean itself. In a 1981 report, "Satellite Altimetric Measurements of the Ocean", the Topex Science Working Group summarised the subject:

"The large-scale movement of water in the ocean has many direct consequences for life on Earth. Of these, perhaps the most important is its amelioration of the world's climate. Without the ocean, large areas of the Earth on which we live would either be unbearably hot or unbearably cold compared to their present states, and life as we know it would be very different. Two processes are involved. First, the oceans carry roughly one-half the heat supply moving from the equator to the poles (the atmosphere carrying the remainder), thus greatly reducing the very large temperature contrasts that would otherwise occur. Second, the large heat capacity of the sea greatly reduces the seasonal fluctuations in temperature, especially at higher latitudes, leading to the equable climate of our continent.

"The ocean is important in a great variety of other ways. It has been fished for food since prehistoric times and today provides a large fraction of the world's food supply. Yet only a few very limited regions of the ocean can sustain important fisheries (the Grand Banks, the coast of Peru, and the Gulf of Alaska, for example), primarily because of the special oceanic flows required for high productivity. These special environments are often fragile, waxing and waning in ways as yet unpredictable (the Peruvian and California anchovy fisheries are prime examples); and the conditions that lead to particularly good fishing at one time and place and not at another are usually determined by oceanographic and meteorological conditions on a much broader scale."

In this artist's conception, a generic representation of the satellite for the Topex/Poseidon oceanographic mission, a joint endeavour between NASA and ESA, is shown in orbit. *NASA/ESA*



The general circulation of the oceans is defined as the large-scale, time-averaged movement of water. Superimposed on this flow are a variety of time-dependent processes which can produce larger effects than the general circulation, making that circulation difficult to characterise. Both categories are important.

Water movements are powered and modified by many factors: winds; solar heating; evaporation; the gravity of Earth, Sun and Moon; land masses; and the rotation of the Earth. Water movements with spatial scales greater than approximately 30 km and time scales over about a day are not only relevant to the general circulation but also exhibit a property known as "geostrophic balance". The Greek word *strophe* denotes the act of turning and "geostrophic" relates to forces arising from the rotation (turning) of the Earth.

The geostrophic mechanism balances the gravitational force that makes water run downhill (from hills of water comprising the ocean topography) with the Coriolis force due to the Earth's rotation. Fluid at the top of a water hill starts to flow down the slope but is deflected to one side by the Coriolis force. The result is that the water does flow downhill slowly, but most of its motion is along the side of the hill: geostrophic balance has occurred. *En passant,* the physical origin of the Coriolis force is easy to visualise. If an object were launched from the north pole of the Earth, the rotating Earth would turn under the object as the latter

sped southward. To an Earth-based observer the object would appear to be deflected somewhat towards the west. If one chooses to explain this deflection by a force, in place of appealing to the rotational geometry, then, *voila!* We have the Coriolis force. Let the object in question be a parcel of water moving down the north or south slopes of a hill of water and the geostrophic dynamics result.

Although geostrophic balance is important for shaping ocean topography, the elevation differences which participate in establishing this equilibrium are small. Typically, the topography of the ocean surface associated with the general circulation is on the order of tens of centimetres to metres. For example, the Gulf Stream might typically exhibit 130 cm elevation changes over a 100 km distance. The period of variability of that structure ranges from days to years.

Oceanographers and other Earth scientists have found it convenient to reference topography with respect to a mathematically defined surface called the "geoid"; the geoid is, by definition, a gravitational equipotential (in every day life, the surface of a level table approximates a local portion of an equipotential surface quite well – a ball placed on it would not roll due to gravitation). The geoid itself varies by about 100 m compared to a reference ellipsoid.

The upshot of the above discussion is that very accurate measurements of the level of the ocean are required if one is to detect the metre or so of topographic excursions ascribable to the general circulation and its variability. It is not difficult to see that the principal quantities to be subjected to the most careful measurements are the altitude of the satellite above the geoid and the distance from the satellite to the surface of the ocean. With these quantities in hand, a simple calculation furnishes the level of the ocean's surface with respect to the geoid. Repeated measurements then allow separation of time-dependent phenomena, and the topography associated with the general circulation is obtained. The Topex/Poseidon orbit has been designed to repeat its ground-trace pattern every ten days, to within an accuracy of one kilometre.

The radar-altimeter systems measure the round-trip light time from the satellite to the average sea surface in the footprint at the nadir point. This time is converted to distance by knowledge of the velocity of the altimeter's radar signal through the atmosphere.

The NASA radar altimeter will employ two frequencies: a prime channel in Ku-band (at 13.6 GHz) and a secondary channel in C-band (at 5.3 GHz). By properly combining the measurements from these two channels, the signal delay due to electrons in the ionosphere can be derived, allowing a more accurate conversion of time to distance. Additional information about the medium through which the altimeter's signal travels will be obtained in measurements of the subsatellite tropospheric water-vapour content by means of a passive microwave radiometer carried onboard. The NASA altimeter's precision is estimated to be two to three cm.

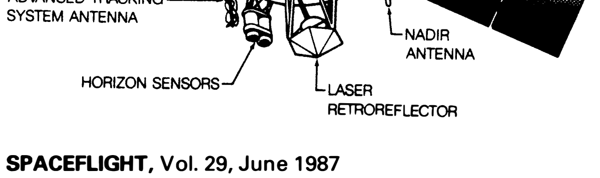
Heritage for the NASA altimeter comes from the instrument carried on the 1978 Seasat oceanographic satellite. Further development has been carried out for the past four years at the Applied Physics Laboratory of Johns Hopkins University.

The CNES Poseidon altimeter will utilise a single frequency, centered at nearly the Ku-band frequency employed by the NASA instrument. Both altimeters use a common antenna. An operational time-sharing plan will allow the science goals to be met with the ionospherically corrected US altimeter while permitting the necessary operating time for the development activities of the CNES altimeter. The CNES altimeter is a new design employing solid-state technology. One of the goals is for this instrument to be the forerunner of subsequent CNES altimeter designs that could be flown on other satellites to provide long-term observation of currents required for climate studies.

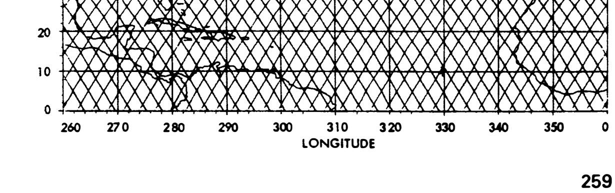
The major error source in the measurement of the ocean topography comes not from the altimeter but from uncertainties in the satellite's height above the geoid. Consequently, careful attention must be paid to the orbit-determination process in order to achieve the desired total accuracy of 13 to 14 cm for sea-level measurements (as mentioned, the NASA altimeter's portion of the error budget is two to three cm).The major error source, in turn, for the orbit determination is uncertainty in the specification of the gravity field of Earth. Hence, a Gravity Field Improvement Program is underway and, by launch, could yield a factor-of-two improvement in knowledge of the gravity to be experienced in the Topex/Poseidon mission's orbital environment (an altitude of 1334 km and an inclination of 63.1 degrees).

Several systems will be used to collect tracking data in support of orbit determination: NASA'S TRANET and the French DORIS system will be prime, with laser tracking as a backup and as a complementary mode with high-precision capability. Signals from the US GPS (a constellation of navigation satellites) will be

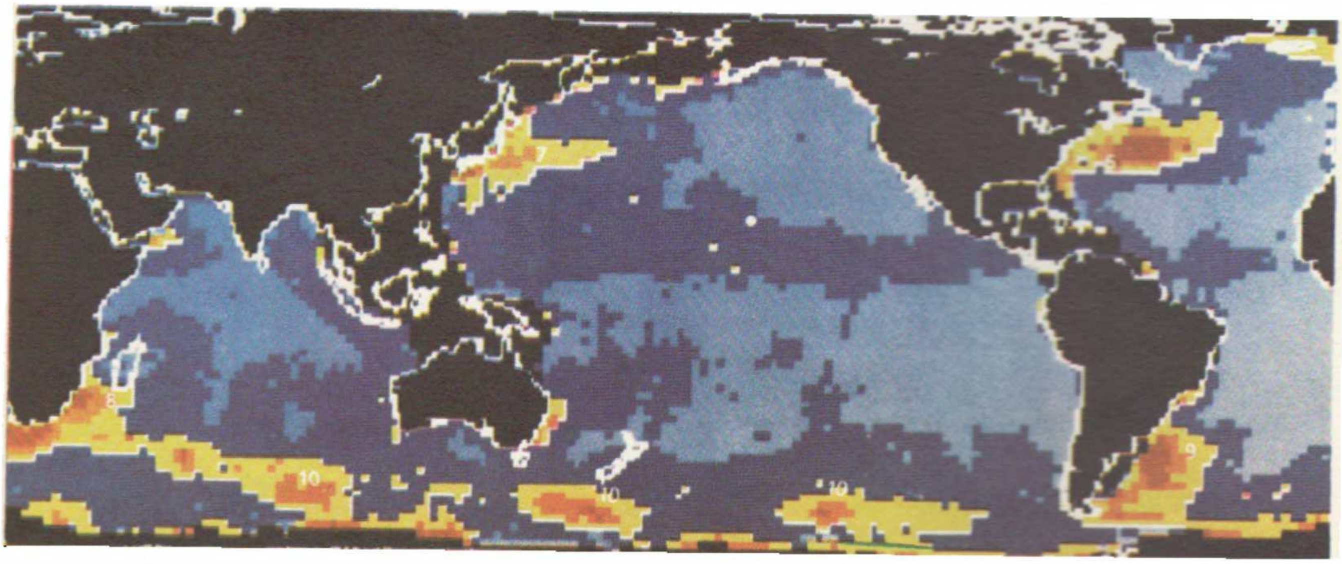
Schematic Topex configuration showing the location of the primary instruments.



Ten-day coverage of Topex over the North Atlantic Ocean.



Sea Surface Topography: This map of the average sea surface topography – the marine geoid – was produced from 70 days of Seasat Altimeter data. The results clearly show the relationship between the ocean surface and the changes in gravity caused by the underlying ocean-bottom topography. Since the ocean surface predominantly follows the Earth's geoid, this dramatic image is especially useful for charting poorly surveyed areas of the world such as the Southern Ocean surrounding Antarctica. This image, which has a spatial resolution of about 50 km (31 miles) was computer generated and the changes are revealed as if the map were illuminated from the northwest. Seen here are the characteristic features of the ocean floor: the mid-ocean ridges, trenches, fracture zones, and seamount chains. Clearly visible are the mid-Atlantic ridge(1) and associated fracture zones(2), the trenches along the west and northwest margins of the Pacific(3), the volcanic Hawaiian Island arc(4) and the Emperor seamount chain(5). *NASA*



Ocean Currents: Superimposed on the mean surface, or the marine geoid, there is a time-varying sea surface topography that is directly related to the variability of ocean currents. These time-varying currents can be calculated from data collected during repeated orbits of the satellite. The mean or constant height along many repeated orbital paths is principally due to the (constant) going while the ocean surface variations due to changing currents are the deviations above and below this mean. Shown here is a global map of the variability of the sea surface topography about the mean for one month during September and October 1978. The largest deviations, 10 to 25 cm (4 to 10 inches), are associated with the strong western boundary currents (yellow and orange). These currents include: the Gulf Stream(6), the Kuroshio Current(7), the Agulhas Current(8), and the Brazil-Falkland Confluence(9). Large variations also occur in the West Wind Drift Current around Antarctica(10). An important revelation from Seasat's mission is the relatively small variability (light blue) over most of the oceans during this one month period of Altimeter measurements. *NASA*

employed in an experiment for the mission to determine if they could help reduce the total error budget. The Goddard Space Flight Center is responsible for determining the precision operational orbit based upon the tracking data. Support is given by the project's Precision Orbit Determination Task Group, headed by Dr. Byron Tapely of the University of Texas.

Scientific data and engineering telemetry will be returned via NASA's Tracking and Data Relay Satellite System (TDRSS). All data will be returned to JPL, where operations are to be conducted, and the data relevant to the CNES experiment will be stripped out and shipped to Toulouse. Both countries will produce Geophysical Data Records based on these data.

The satellite will be supplied by the US and negotiations are currently underway with the Fairchild Space Company for the purpose of yielding a contract to build the vehicle. This vehicle would be a Modular Multimission Satellite (MMS), originally designed by NASA's Goddard Space Flight Center. Although the prime mission extends for three years (with the first six months devoted to data validation), the satellite's two primary expendables – hydrazine for attitude control and the lifetime of the solar panels – will be sized so as to permit a five-year mission.

Reflecting on the long programmatic trail from development flight project to the present, and the years ahead before results are obtained, Topex project manager Charles Yamarone of JPL said: "Doing something significant to help our situation here on Earth helps to keep us persevering." Prior to assuming his position on Topex, Yamarone was the Information Processing System manager for Seasat, with responsibility for producing the Geophysical Data Records for that project. Michel Dorrer manages the CNES portion of the joint mission.

AUGUST 1987 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

* * *

Spaceflight is distributed in the UK and overseas through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH, England. Tel. 0344 884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L. Ltd., Aylesbury, Buckinghamshire, England.

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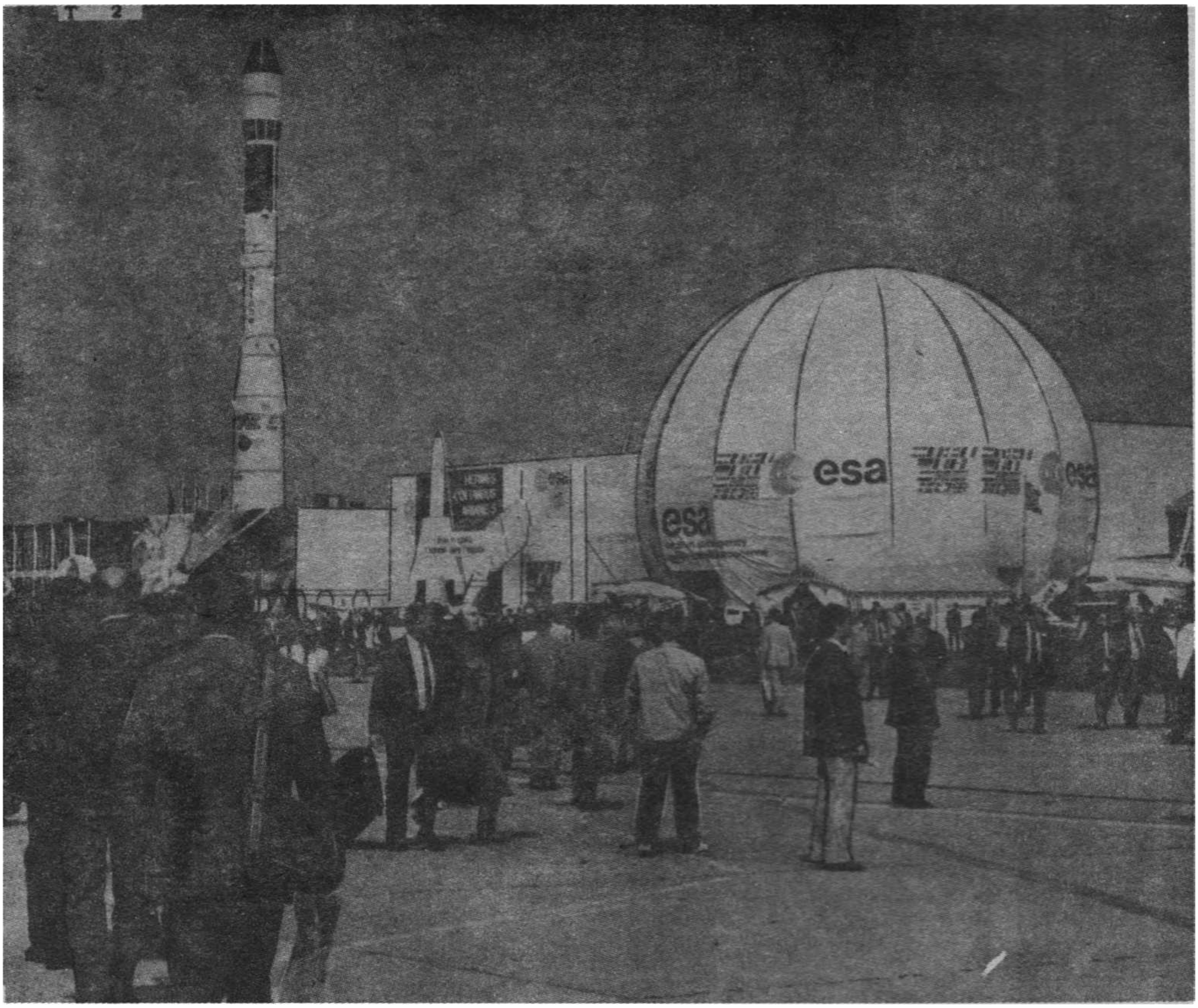
Spaceflight

The International Magazine of Space and Astronautics

Vol. 29 No. 8 August 1987

Front Cover: A farewell wave by cosmonauts Yuri Romanenko and Alexander Laveikin prior to their launch on February 5, 1987 from Baikonur in a Soyuz TM-2 spacecraft. Two days later they docked with the Mir space station and have since been actively engaged in its operations. A report of the Mir mission begins on p.282.

Back Cover: Many designs for the Space Station have previously been proposed, and here we illustrate the ultimate intent – a site for scientific experiments and observations, a microgravity manufacturing centre, a place to assemble and repair spacecraft, and the jumping off point for journeys to the Moon and planets. *TWA*



An Ariane rocket model and the dome-shaped ESA pavilion at the 1987 Paris Air Show.

Show Highlights Latest Space Technology

Pictures and Reports
by Joel Powell
and Clive Simpson

Space technology featured prominently at the 1987 Paris Air Show – the world's biggest aerospace showcase – held at Le Bourget in June. Total attendance was estimated at 400,000, a 20 per cent increase on 1985, and key elements from the world's major space programmes of both the present and future were on display.

Dominating the outdoor static show areas were a life-size model of an Ariane 1, next to the Arianespace stand, and the giant white sphere of the European Space Agency pavilion which housed models of all the main European programmes.

A second ESA pavilion, linked to the first, was devoted to the theme 'Man in Space' and displayed for the first-time a full-size model of the Hermes spaceplane (see p.271) and one of the Columbus space laboratory components.

The French President, Francois Mitterand, emphasised the importance of the Ariane 5/Hermes programme during his speech at the opening of the Show on June 11.

The Soviet pavilion was equally impressive, containing a full-scale mock-up of the Mir space station complex, including Kvant, a Progress supply vehicle and Soyuz TM cosmonaut transporter.

Actual-size models of the Vega probe (Venus and Halley's comet) and the Phobos spacecraft (pictured opposite) were also on display. The latter showed the new modular design that will be used for future Soviet unmanned interplanetary missions. Two Phobos spacecraft will be launched towards Mars and its moons in July next year (*Spaceflight*, Sept/Oct 1986 p.348).

China, present for the first time, displayed scale models of its series of rockets, (see p.272), current and planned, that will compete in the commercial launcher market.

Space hardware from the United States included models of the Titan 3 commercial launcher (picture on p.279), and the X-30 aerospaceplane. NASA, in the US Pavilion, based its display around a film show.

UK companies also had a strong presence, with the British Aerospace/Rolls Royce Hotol project (above right) featuring prominently. The British National Space Centre, still awaiting government approval of a national space plan, backed up the UK effort with its first-ever stand at the show.

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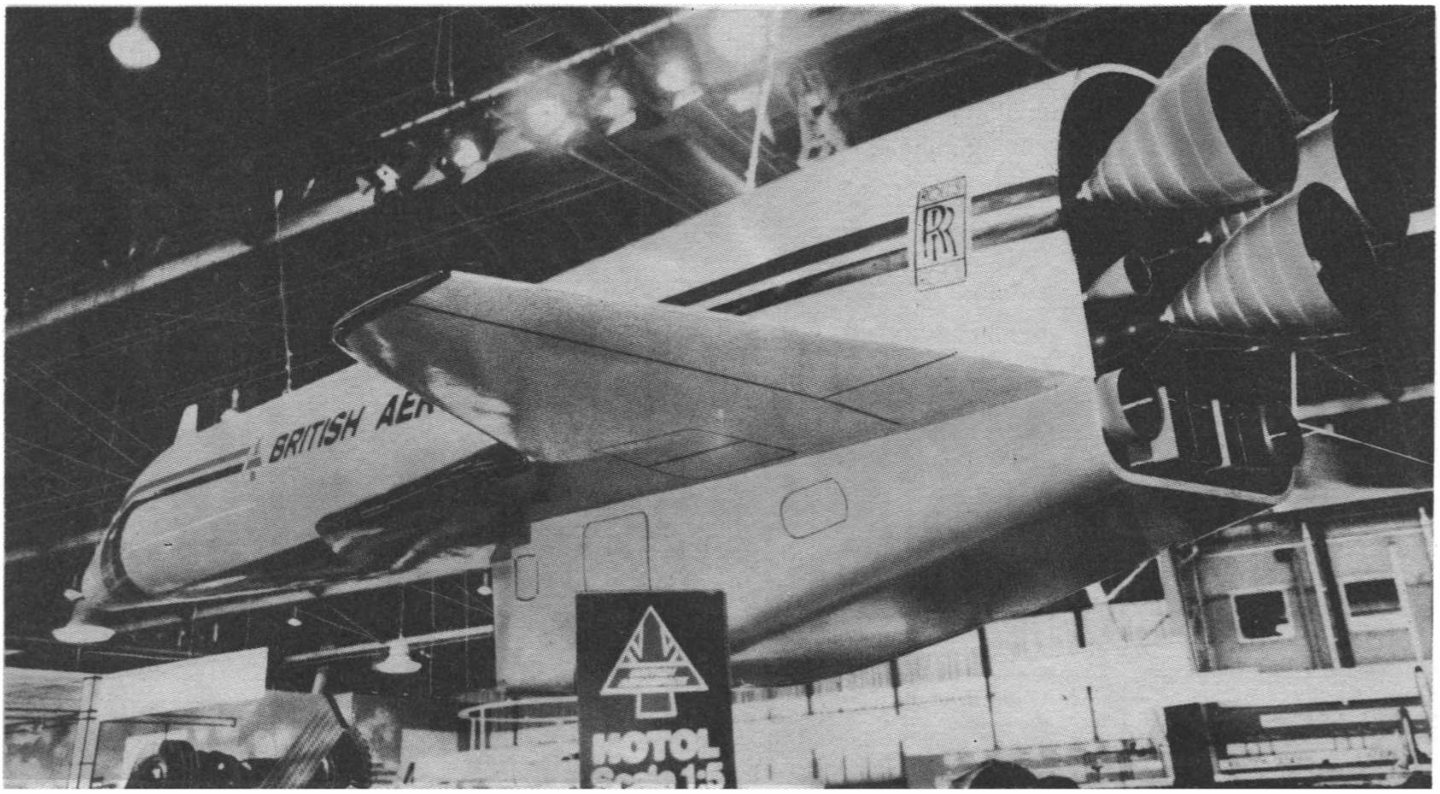
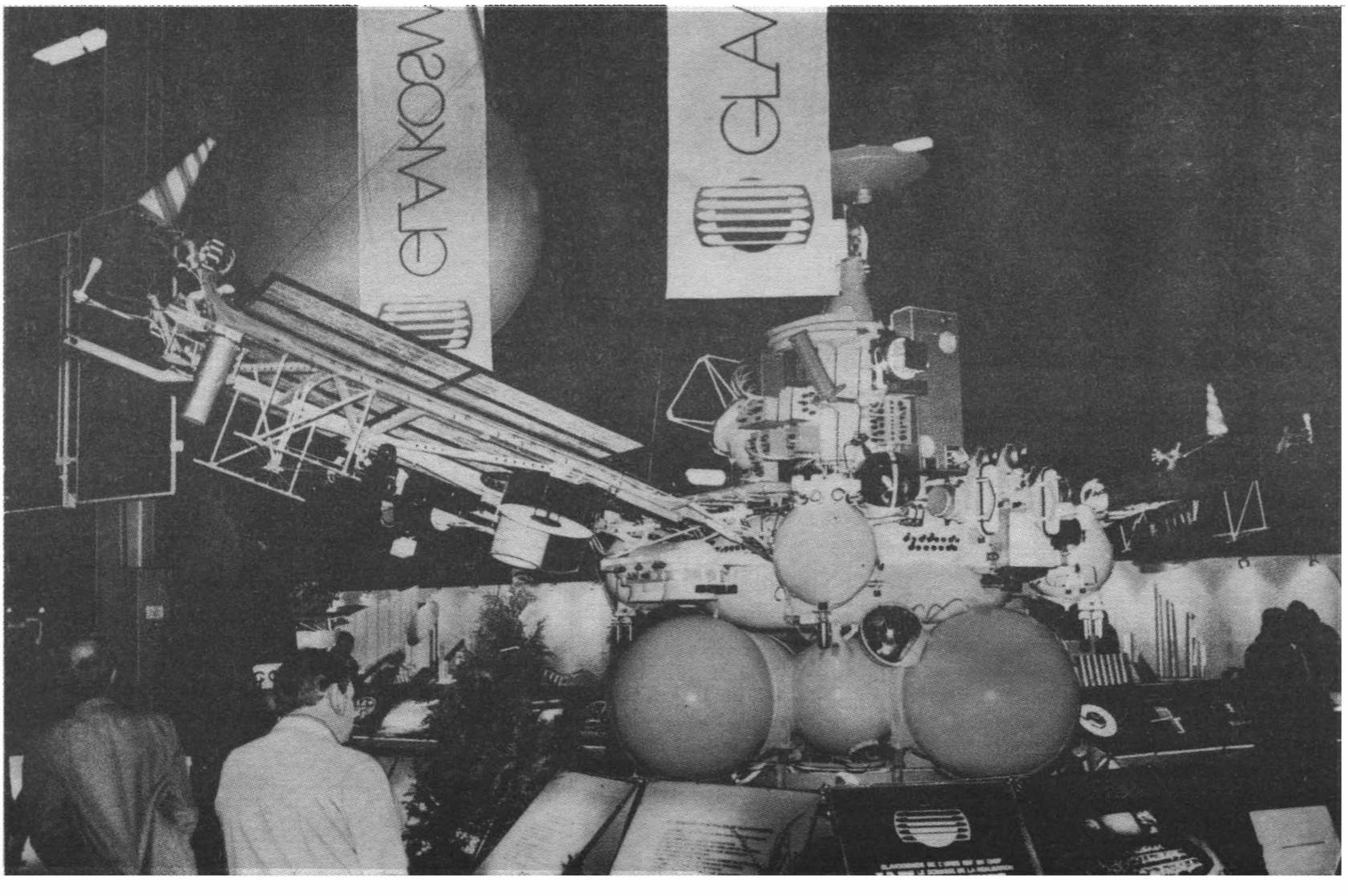


The one-fifth scale model of Hotol dominated the British Aerospace stand and showed the nozzle arrangement of the four main engines and the new air intake design under the fuselage.

A full-scale replica of the Phobos Mars spacecraft. Two such probes, each carrying landers, will be launched in July 1988.



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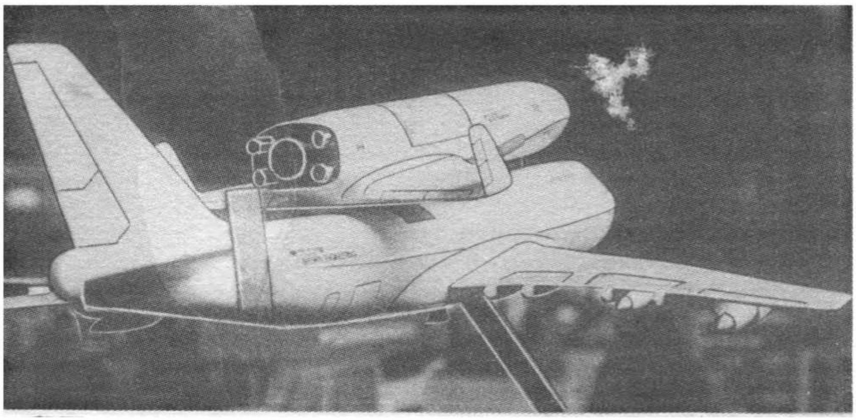


Aircraft-Launched Spaceplane

Model of a spaceplane concept on display at the Teledyne Brown Engineering stand.

The vehicle, launched from a B-747 carrier aircraft, would be capable of carrying several tons to low-Earth orbit and back at low cost.

Its design is based on current technology and it would be completely re-useable.

New Boosters Will Increase Delta Capacity

The US Air Force has authorised McDonnell Douglas to build 42 foot long "stretched" solid rocket boosters for the Delta II launch vehicle.

The improvement will enable the rocket to lift more than 4,000 lb (1,800 kg) into geosynchronous transfer orbit, according to details given at the Paris Air Show.

Development of the new booster, called Graphite Epoxy Motors (GEMS), saves a step in the process of upgrading the Delta. The company originally planned to develop a 36 foot long GEM first.

"We presented data on stretched GEMs to the Air Force and they decided that going to the stretched version now was a low-risk, cost-effective way to increase the Delta II's payload capacity", said John Porter, Director of Delta II programmes for the Company.

McDonnell Douglas will build two versions of the Delta II. The first is model 6925 which use existing 36 foot long rocket motors with steel casings and will begin launching Air Force Navstar Global Positioning System (GPS) satellites in 1988. The second is the model 7925 which will use the new stretched GEMs and will begin launching in mid-1990.

The 6925 will lift 3,190 lb (1,447 kg) into geosynchronous transfer orbit, while the 7925 will be able to launch payloads weighing up to 4,010 lb (1,819 kg) into that orbit.

Hercules Aerospace Company in Magna, Utah, won the subcontract to build the GEMs for the Delta II last December. The Company will begin building the first GEM late this summer and will start testing it in November. The first motor will undergo static test firing in early 1988.

Hotol Engine Calculations

Rolls Royce announced at the Paris Air Show that 18 months of work has confirmed the original estimates for the weight and performance of the company's revolutionary Hotol engine proposal.

The preliminary design and proof-of-concept programme began in February 1986 and included the examination of a number of alternative propulsion concepts in addition to the engine for British Aerospace's Hotol spaceplane.

Rig testing of critical components of the Hotol engine, designated the RB545, has been carried out in as realistic conditions as possible by a small team of specialists at Rolls-Royce's Ansty plant, near Coventry.

Stewart Miller, Rolls Royce Director of Corporate Engineering, said: "The test programme has produced some exciting and positive results.

"We have made significant progress in the last 18 months towards confirming the original ideas for such a propulsion system, which seized everyone's imagination three years ago.

"The rig testing and project design studies, which are being carried out at Rolls-Royce's Bristol plant, are proceeding to schedule, enabling us currently to define follow-on technology and associated programmes.

"We have been in discussion with European industry and remain committed to the extension of the programme into Europe."

Satellite-Based Transmission System

The first live demonstration of PRODAT, a satellite-based telex and data transmission system for air travellers, was held at the Paris Air Show.

Racal-Decca Advanced Development Ltd (RDAD) was awarded a contract by ESA for the development and production of five data-only terminals within its PRODAT programme. The UK is among seven ESA members to back the project.

PRODAT is a development satellite communications relay system for data transmission between mobile users on land, at sea and in the air. It will allow aircrew data communications and passenger telex facilities via ground data networks throughout a flight, without resorting to often unrealiable HF radio links.

Transportes Aereos Portugueses (TAP) will be the first airline to take part in trials with PRODAT due to be installed on board one of its Tristar aircraft in September this year. Other trials, including the UK Civil Aviation Authority's BAE 748 aircraft, will follow.

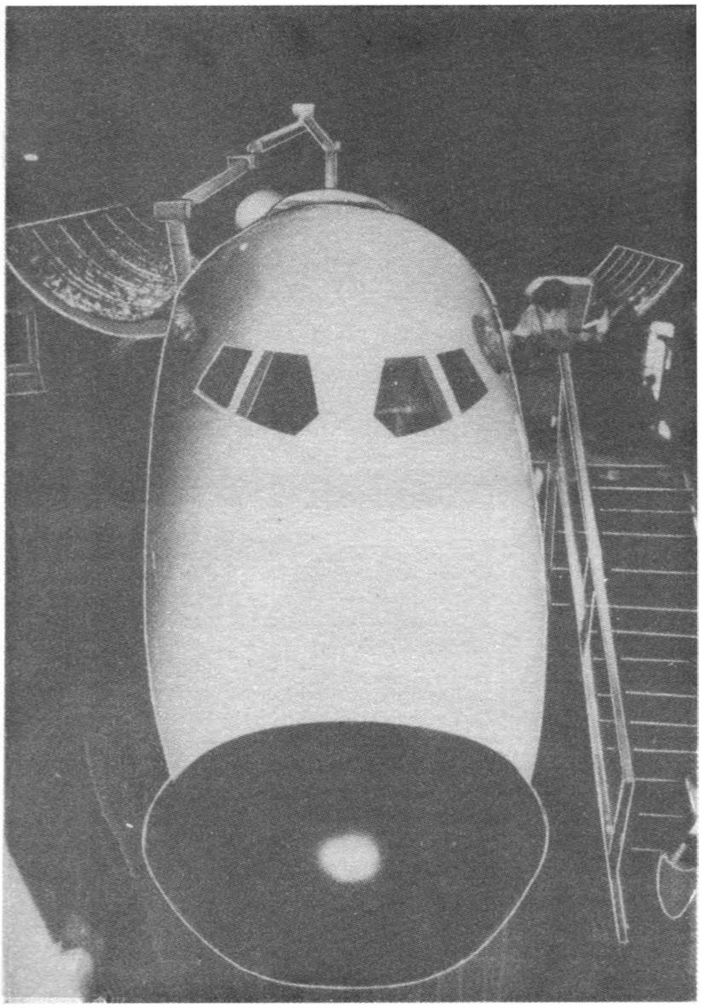
Ariane Set for Return to Action

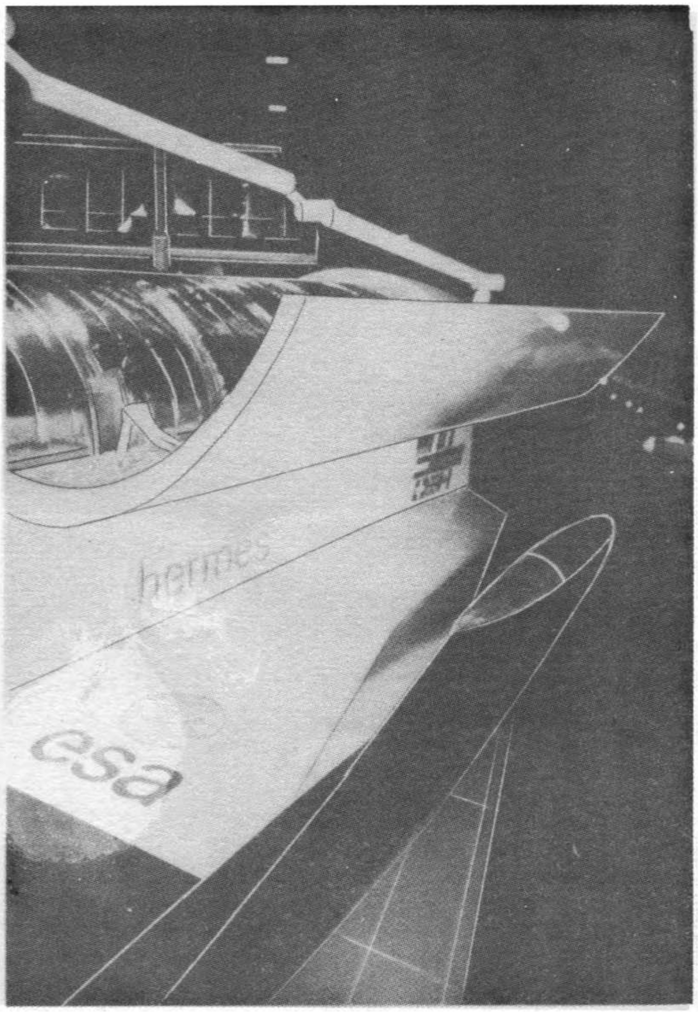
Launch of the next Ariane is expected at the end of this month, with August 29 being named by Arianespace staff at the Paris Air Show as the target date.

The Ariane V19 launch campaign started on June 2 marking the resumption of operations after a lengthy period of intensive work devoted to implementing corrective measures on the third-stage hydrogen/oxygen engine. Payload for the Ariane 3 launcher will be the Aussat K3 and ECS-4 satellites.

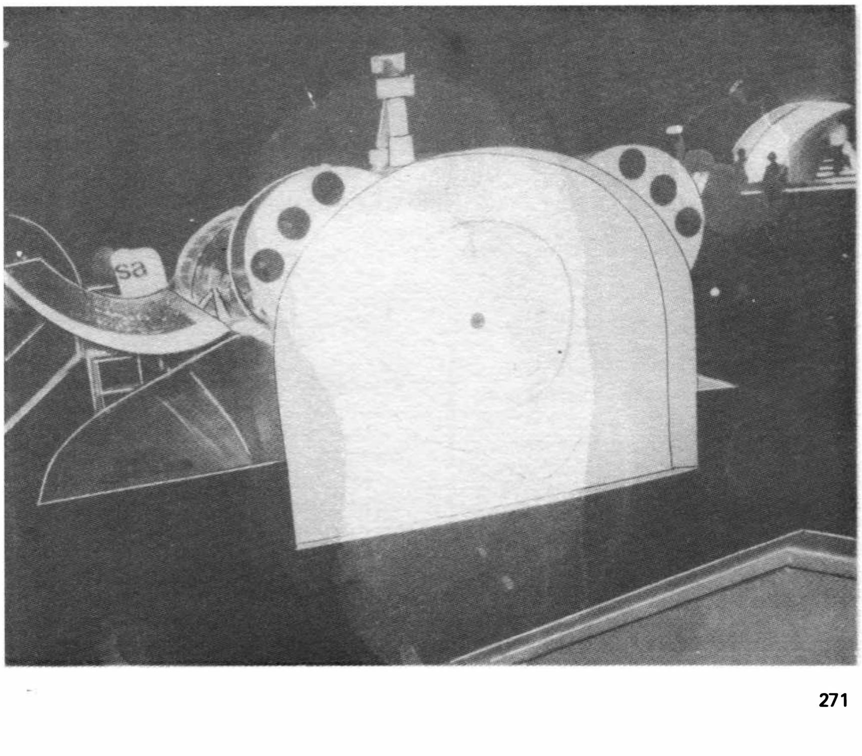
Two further launches planned for this year are: October, TV Sat 1 (Ariane 2) and December, G Star III and Telecom IC (Ariane 3).

The first Ariane 4 launch is scheduled for January 1988 but Arianespace is leaving open an option to bring the flight forward, possibly to November of this year.





Full-scale Hermes Model



Detailed inspection of the current Hermes manned spaceplane configuration was possible on a full-scale mock-up in the ESA pavilion.

The head-on view (above) bears similarities to the US Shuttle and the remote manipulator arm can be seen extending in the background.

Large outer doors (above right) will open in orbit for thermal cooling. Hermes will not have an exposed payload bay and the internal skin of the fuselage will also act as a thermal radiator.

The up-turned wing tip in the foreground of this picture can also be seen. These will serve as twin vertical stabilisers instead of a single fin on the fuselage.

The airlock, which will allow crew and equipment transfer when docked to a space station, can be seen in the right-hand view.

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Japan Plans Own Space Station

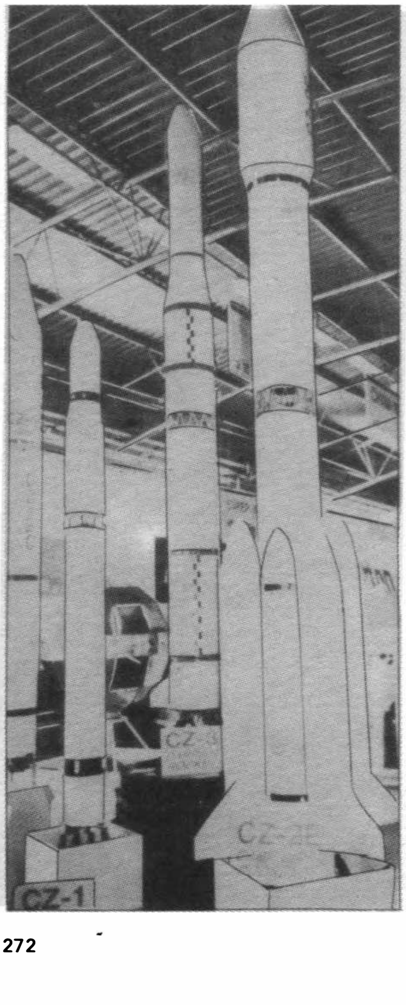
Details of Japanese spaceplane studies were recently presented in London by Mr. Toshio Akimoto of the National Space Development Agency of Japan (*Spaceflight*, June 1987, p.227).

Manned space flight is regarded as a key area by Japan. There are plans for a Japanese Spacelab mission after US Shuttle flights resume and Japanese payload specialists were selected in the autumn of 1985. Japan is also one of the participating countries of the international Space Station to which it plans to contribute an autonomous manned module (***Spaceflight***, November 1986, p.391).

New plans for Japan's advance into space have now been revealed which aim to put a Japanese space station in orbit by 2010. The move is seen as essential if Japan is to continue its commitment to new technology and cooperate as an equal with other advanced nations.

The space station project is closely linked to that of the Japanese shuttle and will provide a coordinated follow-on development beginning in the year 2000 and operational activities that extend well into the 21st century.

Space policy in Japan is formulated from time to time by Japan's Space Activities Commission for a 15-year time span. In 1978, Earth observation, meteorology and telecommunications were the Commission's main proposal areas and many of these developments have now been realised (***Spaceflight***, Sept/Oct 1986, p.367).



German Hermes Doubts

West Germany, which has so far been an ardent supporter of Europe's Ariane, Columbus and Hermes space projects, may lower its budgetary commitment to these leading ESA projects when its government reconvenes this autumn.

Concern has arisen over possible massive cost increases and their budgetary implications if a German level of contribution were to be maintained at around 30 per cent over a time-scale of ten years. One proposed remedy is to extend the programmes further into the future and the Hermes project, in particular, will be at the centre of the debate.

Chinese Rockets

The first-ever display by China at the Paris Air Show included space hardware and in particular its series of satellite launchers. The CZ2E launcher (foreground) is equipped with solid boosters which will allow it to orbit heavier satellite payloads on a commercial basis.

Landsat Deal for China

The Earth Observation Satellite Company (EOSAT) has finalised an agreement with the Chinese Academy of Science, Peoples Republic of China (PRC) to be the official representative for Landsat satellite data acquired by the Beijing Landsat station. EOSAT, the operator of the US Landsat remote sensing satellite system, will market the new data on behalf of the PRC to a worldwide customer base, which has expanded significantly since the decision by the US Congress to commercialise Landsat (*Spaceflight*, Sept/Oct 1986, p.358).

At present, EOSAT markets image and digital data acquired by the Landsat satellites in both domestic and international markets. The agreement with the PRC allows EOSAT to market data from China that will be available on a commercial basis for the first time. "We are extremely pleased to act as distributor for the People's Republic of China, and expect significant initial data sales from the new station," said Robert Tack, EOSAT Marketing Vice President. Early reviews of Thematic Mapper (TM) and Multispectral Scanner (MSS) products collected by the Beijing station indicate a very high quality processing capability.

Navstar Satellite Delivered

Rockwell International Corporation's Satellite Systems Division has delivered the first satellite of a system which will provide the world's most precise navigational information to a variety of users. This is the US Global Positioning System (GPS), satellites for which are being produced by Rockwell International for the US Air Force. The GPS satellites are part of a multi-service programme designed to meet the navigation requirements of the US and its NATO allies in the 1990's and beyond.

Rockwell will build a total of 28 production (operational) satellites at its Seal Beach (California) facility under a $1.2 billion multi-year contract awarded in 1983. The contract is the largest firm, fixed price satellite contract ever awarded by the US Department of Defense.

The production satellites are capable of launch from either the Space Shuttle or the USAF Delta-II medium launch vehicle. The Navstar system will be fully operational in the early 1990's with 18 satellites transmitting navigation signals to users around the globe, at any time and in all weather conditions. The system's proven precision will enable users to calculate their position to within tens of metres, velocity to within a fraction of a kilometre per hour and time to within one ten-millionth of a second.

Eleven GPS development satellites built by Rockwell have previously been launched to support operational test and evaluation of the Navstar system. More than 700 air, land and sea vehicle application tests were successfully completed, during which the Navstar system met or exceeded all specifications. Although designed for a four year mean mission duration, several of the satellites have exceeded seven years of on-orbit life. This autumn, 50 years of cumulative on-orbit operations will be achieved by these developmental satellites.

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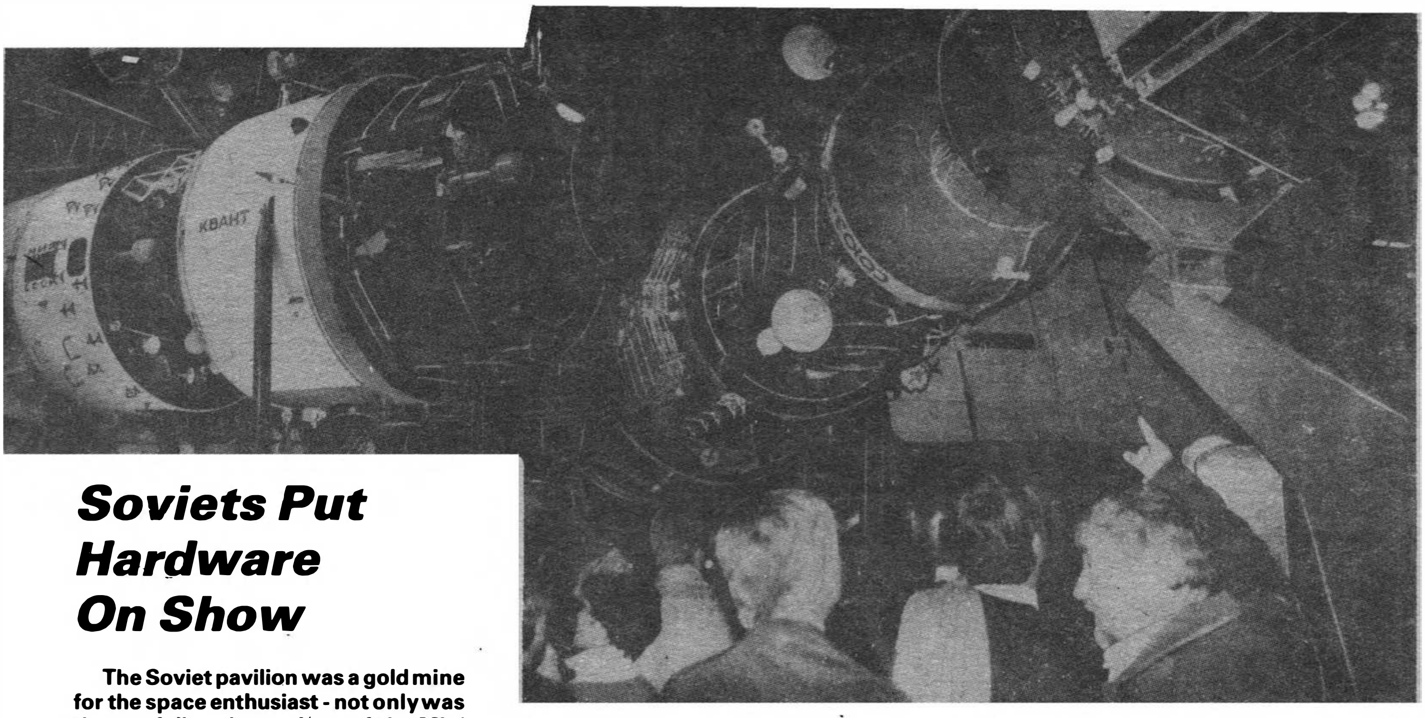


The Soyuz TM crew transfer vehicle is seen docked to one of the five ports attached to the Mir space station in this full-scale model which dominated the Soviet pavilion. The Kvant module (inset) is shown docked to the single aft port. A Progress re-supply vehicle (not shown in the picture) completed the complex.

Soviets Put Hardware On Show

The Soviet pavilion was a gold mine for the space enthusiast - not only was there a full-scale mock-up of the Mir/Kvant/Soyuz TM complex but also a replica of the Phobos spacecraft to be launched towards Mars next year, *writes Joel Powell.*

On display was a Soviet EVA space suit, appropriately decked out in French regalia to represent Jean Loup Chretien's flight to Mir which will also take place in 1988.

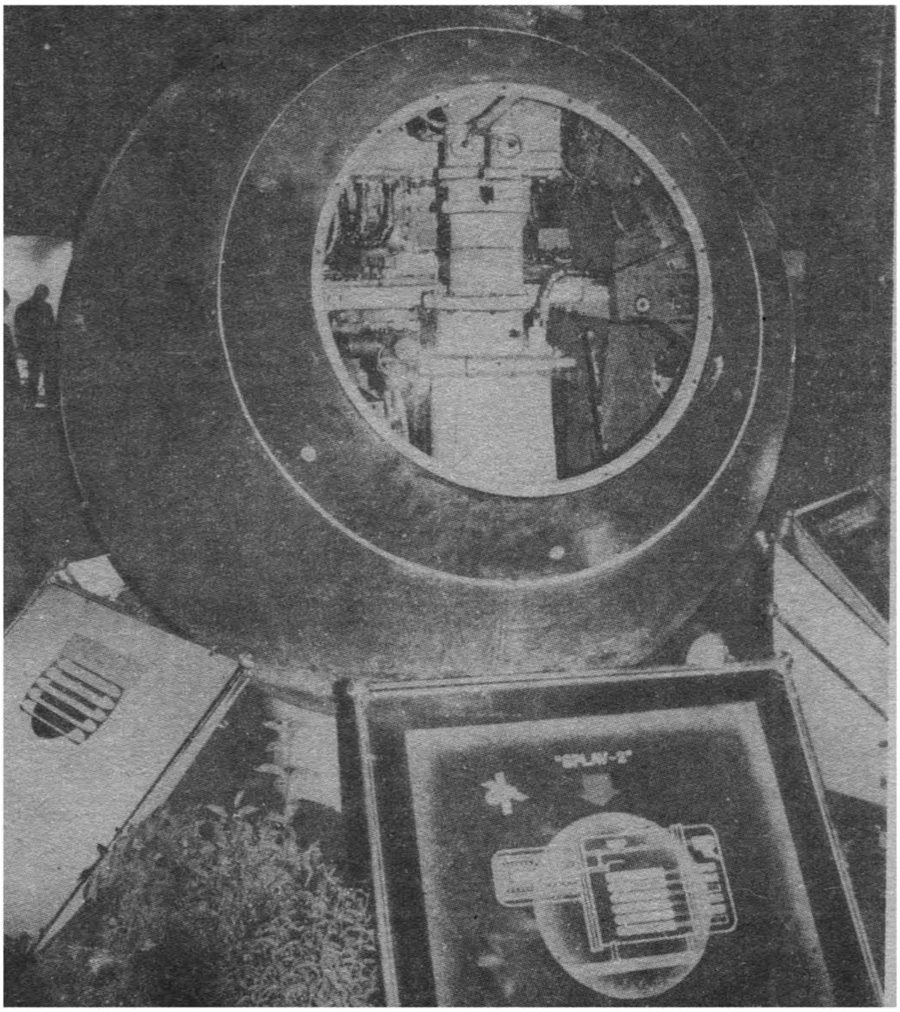
Another interesting item was the Vostok-based recovery module (pictured right) of the Cosmos materials processing programme. According to details presented, the payload (the three apparatus are visible inside) represents Cosmos 1841 (April 24, 1987) - the previous two missions were Cosmos 1645 (1985) and 1744 (1986).

The 400 kg payload of Cosmos 1841 was stated to be: the Kachtan electrophoresis unit (interferon production); the Splav 2 crystal growth science investigation; and a crystal growth science investigation.

During the Show the Soviets also announced the availability of the Mir space station for commerical processing and in-orbit microgravity experiments.

The basic price for a commercial payload (dimensions 1 m long by 60 cm in diameter) is about £10,000, with weight subject to individual agreement.

Visitors to the Soviet pavilion were able to climb aboard the Mir basic module and view the forward control stations, aft facilities and a cosmonaut's personal compartment. A window in the side of the Kvant module revealed the control station and the MKF-6M camera (see picture on p. 282) installed in the "floor".

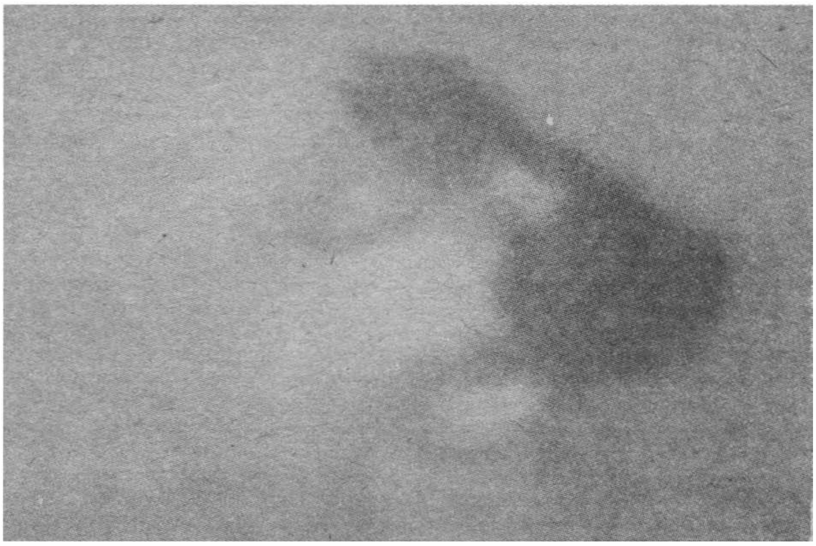


INTERNATIONAL SPACE REPORT

New View of Comet Halley Nucleus

by *Ian Ridpath*

This is the definitive view of the nucleus of Halley's comet. It is a composite of 60 pictures taken during the last five minutes before the Giotto space probe made its closest approach to the nucleus on March 13, 1986. The composite was made by Harold Reitsema and Alan Delamere of Ball Aerospace, Boulder, Colorado.



Resolution of the composite image ranges from 8000 m at the lower (southern) end of the nucleus to 100 m or better at the northern tip. Giotto's camera was programmed to centre each image on the brightest part of the nucleus, which happened to be the jets of dust shooting out from the northern end. During the last three minutes of the approach the nucleus was too large for the camera's field of view, so coverage was restricted to a region of decreasing size centred on the bright northern jet. The last image was taken 127 seconds before closest encounter, at a distance of about 1,200 km, after which the spacecraft's attitude was disturbed due to impacts by dust particles and the camera could no longer track the comet.

Difficulties in superimposing the images included removing distortions caused by the line-scanning mode of the spacecraft [1]. Each image has a different distortion due to the changing position of the comet relative to the spacecraft. Another complication was caused by dust impacts which slightly altered Giotto's spin axis during the encounter.

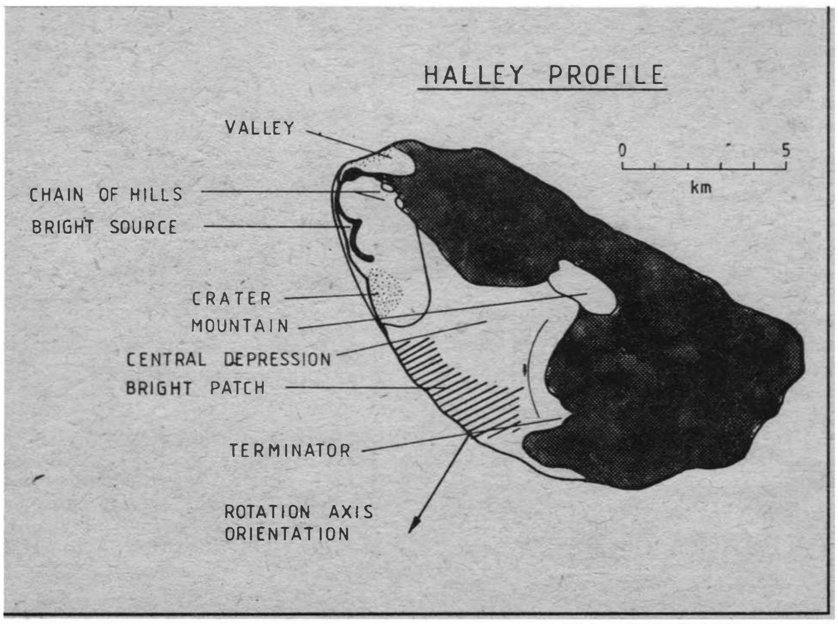
Seen in this projection, the nucleus is potato-shaped, with dimensions of 14.9 km by 8.2 km, although the full length is estimated from the Soviet Vega pictures to be about 1 km longer. Features identified on the nucleus are shown in the sketch below. The Sun is to the left and slightly behind the plane of the page, so more than half the nucleus is in shadow. The active areas are all on the sunward-facing side.

At the northern tip of the nucleus are several bright spots from which strong dust jets emerge. In the middle of the nucleus is a brighter surface region associated with a broader jet. At the southern end of the nucleus is a weak jet. The whole nucleus is seen against a background of dust illuminated by sunlight.

A surface elevation dubbed the "mountain" rises into sunlight from the shadowed part of the nucleus. This feature, and a notch-shaped valley near the northern tip, indicate the existence of slopes on the nucleus with heights of at least 400 m. South of the brightest jet region is a shallow crater-like depression, over 1 km in diameter.

The temperature of the surface of the nucleus is about 350 K. The surface is covered in a dark crust of porous dust, which reflects only two to four per cent of the sunlight hitting it. The thickness of the crust is still uncertain. Estimates range from 1 cm or less to more than 10 m [2]. Probably the thickness of the crust varies over the nucleus, being thinnest in the most active regions beneath the crust, the nucleus is mostly water ice. Eighty per cent of the gas given off by the comet was water vapour, 15 tonnes per second. One surprise is that the nucleus seems to have a very low density, only a few tenths of a gram per cubic centimetre, so that it is more like a snowdrift than a snowball. The nucleus rotates around its shortest axis every 2.2 days. But this axis also wobbles, or precesses, every 7.4 days [3].

One controversial theory, put forward by Sir Fred Hoyle and Chandra Wickramasinghe, is that the dust from comets contains living cells. This possibility has now been ruled out by analysis of the dust of Halley's comet by a mass spectrometer aboard the Soviet Vega 1 probe [4]. Evidence from isotope ratios of carbon, sulphur and nitrogen in Halley's comet confirms the view that comets formed from the same cloud of gas and dust as the planets, and not in interstellar space. Halley's comet is indeed a fossil relic from the birth of the Solar System.



References
1 Reitsema, H J et al, in Proceedings of the 20th ESLAB Symposium on the Exploration of Halley's Comet, ESA SP-250, 1987
2 Reinhard, R, ESA Bulletin, February 1987, p 62
3 Julian, W.H, Nature, vol 326, p 57, 1987
4 Kissel, J, and F R Krueger, Nature, vol 326, p 755, 1987.

INTERNATIONAL SPACE REPORT

Logica Wins Eutelsat Contract

Eutelsat, the European Telecommunications Satellite Organisation, has signed a £6.3 million contract with Logica to supply the Telemetry, Command and Ranging (TCR) facilities for in-orbit control of up to three Eutelsat II satellites.

The initial system is scheduled for delivery in April 1989 and the contract includes options worth a further £700,000 for extensions so that a total of up to six satellites may be controlled using the same system.

The TCR will provide Eutelsat with a cost-effective and highly responsive means of controlling satellites, the first of which will be launched in late 1989, which will gradually replace the Eutelsat I satellites, and will be used primarily for television transmission, telephony and business services.

Facilities supplied by Logica will include a Satellite Control Centre (SCC), located in Paris, and two TCR station baseband facilities, one near Sintra (Portugal), the other near Rambouillet (France). A back-up SCC will also be delivered. Logica will provide equipment to allow data communications between sites, and, as prime contractor, will manage the project.

Construction of the Eutelsat II satellites is being carried out by a European industrial consortium led by Aerospatiale as prime contractor with Alcatel Espace a major partner.

New Satellite Test Programme

An extensive programme of new mechanism tests is underway at the European Space Tribiology Laboratory (ESTL), Cheshire, UK, as part of the Inmarsat 2 and Olympus communication satellite projects.

ESTL will be responsible for the lubrication, assembly, testing and qualification of the mechanisms used to rotate the solar panels on Inmarsat 2. A new solar array drive mechanism design has been developed for Inmarsat using thin section angular contact ball bearings specifically designed to withstand launch vibration without the need for any protective off-loading mechanism.

Space Capacity Expanded

A new 'clean' room for handling high reliability electronic, electrical and electromechanical satellite components has been installed at IGG Component Technology of Cosham, Portsmouth.

IGG is expanding its test facilities, installing equipment for burn-in, extended thermal shock, acceleration testing, and radiographic examination. The Company is currently working on two Italian satellites, the 'Anthorack' Spacelab experiment to test and measure astronaut responses, Meteosat and the ERS 1 Earth resources satellite.

Westland's Space Project

Westland Aerospace Division at Cowes, Isle of Wight, has contributed to a botany space laboratory as part of Europe's Eureka high technology initiative. Engineers have been managing a project to produce an Earth-based prototype one g centrifuge intended to demonstrate that an experiment to investigate plant growth under microgravity conditions will work aboard a satellite.

In flight, two cylindrical sections of the satellite will contain samples of a plant chosen for its rapid propagation and life cycle characteristics. One section will be a rotating centrifuge providing 'g' conditions similar to those on Earth. The other will not rotate and will therefore provide microgravity conditions. The differing behaviours of plants growing in the two sections will be observed and recorded. The research may eventually lead to production in Space of pure virus-free seeds for use on Earth. The centrifugal section was recently delivered to prime contractor, Dornier Systems of West Germany.

The work represents a return of Westland to Space. Saunders-Roe, predecessor of Westland Aerospace, produced and launched the Black Knight high-altitude research rocket in 1958 and the Black Arrow launcher.

Hermes Assessed at Cranfield

The College of Aeronautics, Cranfield, UK, has been asked by ESA to provide an independent technical consultancy service on a wide range of astronautical topics relating to the Hermes spaceplane.

A team has been formed of 16 senior academics led by Professor Phil Roe and Dr. John Fielding. Aerodynamics, configuration, thermal engineering and avionics are among the subjects being assessed.

Ride Leaves NASA for Defence Job

Astronaut Sally Ride, the first US woman to fly in space, has resigned from NASA and is due to take up a new post with the Stanford University Center for International Security and Arms Control.

Ride, who joined NASA in 1978, became the third woman in space after blasting off aboard Challenger on June 18, 1983. The Soviets sent up women in 1963 and 1982.

* * *

New astronaut candidates will report to the Johnson Space Center in Houston on August 17 to begin a year-long programme of training and evaluation.

There were 1,962 applicants to NASA out of which 117 persons were interviewed and given medical examinations at Johnson before a final choice of 15 was made.

Seven are pilot astronaut candidates and eight are mission specialist candidates. The group includes five civilians and 10 military officers with two of the mission specialist candidates being women.

Dr. Jan D. Dozier.

The candidates are: Dr. Mae C. Jemison, Army Major James S. Voss, Capt. Thomas D. Akers, Capt. Curtis L. Brown Jr., Major Kevin P. Chilton, Major Donald R. McMonagle, Lt. Kenneth D. Bowersox, Lt. Cmdr. Kenneth S. Reightler Jr., Lt. Cmdr. Mario Runco Jr. Marine Capt. Andrew M. Allen, Coast Guard Lt. Cmdr. Bruce E. Melnick. Civilians are: Dr. Jan D. Dozier, C. Michael Foale, Gregory J. Harbaugh and William F. Readdy.

* * *

The Council of the European Space Agency (ESA) has decided to prolong the mandate of its Director General, Prof. Reimar Lüst for two additional years (from September 1, 1988 to August 31, 1990). Prof Lüst, (64) took up office in September 1984, on a four year appointment.

* * *

Mr. Henrik Grage, from Denmark, is the new Chairman of the ESA Council for the next two years. Mr. Grage (46) has been involved in space matters for the last 17 years and was up to now Chairman of the ESA Industrial Policy Committee. He succeeds Mr. H. Atkinson from the UK.

INTERNATIONAL SPACE REPORT

Satellite Search and Rescue

Canadian Astronautics has been awarded a £600,000 contract to upgrade a satellite-aided search and rescue ground station for the UK Ministry of Defence (MoD).

With the upgraded ground station,known as the Local User Terminal or LUT, the MoD will be able to locate aircraft and boats by receiving their distress signals in the 121.5 Mhz and 243 Mhz frequency bands in addition to receiving in the exisiting 406 Mhz frequency band. The distress signals are relayed to the LUT by the Cospas-Sarsat system of five low-altitude satellites.

Installed at Lasham Airfield – a facility of the Royal Aircraft Establishment – the LUT is able to pinpoint signals within two hours over the entire North Atlantic. The upgrade will be operational a year from now.

CAL has teamed with Space Technology Systems Limited of the UK to supply the LUT. Acting as the prime contractor, Space Technology Systems is responsible for project management, customer liaison and post-installation operation and maintenance of the upgraded LUT.

Experiment Will Chart Ozone Gases

Scientists and engineers at Lockheed are designing and building an experiment that will chart a number of gases in the Earth's ozone layer while onboard a NASA satellite.

The experiment, the Cryogenic Limb Array Etalon Spectrometer (CLAES), will continuously measure precise amounts of ozone, methane, carbon dioxide and water vapour and various compounds of nitrogen and chlorine that contribute to the formation of the Earth's ozone layer.

CLAES will be the largest of a series of experiments carried on NASA's planned Upper Atmosphere Research Satellite. Managed by Goddard Space Flight Center, the satellite is being developed in response to concerns voiced in the early 1970s that human activities could cause changes in the upper atmosphere that may have serious consequences for life on Earth.

Concerns have been underscored in recent months with reports of alarming changes in the atmospheric ozone over Antarctica, where an 'ozone hole' has been observed (***Spaceflight***, May 1987, p191). Ozone levels plunge by as much as 60 per cent each Antarctic spring.

The Upper Atmosphere Research Satellite is designed to study phenomena of this kind over most of the Earth's surface for at least 18 months.

CLAES will measure the characteristic infrared radiation coming from each ozone layer gas. To accomplish this the experiment must be kept extremely cold to suppress the natural infrared radiation given off by the instrument surfaces which would otherwise wash out the sometimes very faint radiation from gases in the atmosphere.

To provide the extremely low temperatures required for long periods, Lockheed engineers are designing and building a tank assembly to keep an advanced infrared sensor at a constant temperature between minus 440 and minus 350 degrees F. The super refrigerator, called a cryostat, will carry solid hydrogen, which freezes just above minus 440 degrees F, as a refrigerant for long-term instrument cooling.

UK Thrust in Space Medicine

A team of 25 scientists from Sheffield University are to collaborate with Soviet and American counterparts on the biomedical effects of space flight. The work will be centred at the University's Institute of Space Biomedicine which is due to be officially opened in October in the presence of leading Soviet and American scientists. Director of the Institute is Prof. Tim Scratcherd, who is also head of the University's Department of Physiology.

The work of the Institute will be in support of the recent agreement for UK-Soviet cooperation in space and a decision is awaited on the level of UK Government funding to be provided. The arrangement will provide British scientists with early opportunities for conducting medical experiments in space, possibly within the next two years.

New Marconi Marketing Manager

Marconi Space Systems has appointed Mr. Dennis Cummings as Company Marketing Manager.

He was previously Marketing Manager for the Satellite Communications Division of Marconi Defence Systems at Stanmore and will now coordinate marketing activities to promote business interests in the space market worldwide.

Failure Traced to Lightning

Adverse weather conditions, particularly the presence of nearby lightning strikes, caused the failure of the Atlas-Centaur launch on March 26 (*Spaceflight*, May 1987, p.187).

The findings of the Accident Investigation Board report that the launch was made in violation of the launch commit criteria associated with weather and state: "The most probable cause of the mission failure was launching the AC-67 vehicle into atmospheric conditions conducive to triggered lightning and in violation of the established criteria used to avoid potential electrical hazards."

Among its recommendations the board suggested that criteria should be revised to take into consideration additional knowledge and measurement techniques of lightning phenomena that have been developed since present expendable launch vehicle (ELV) criteria were established.

Mars Observer Launch Date

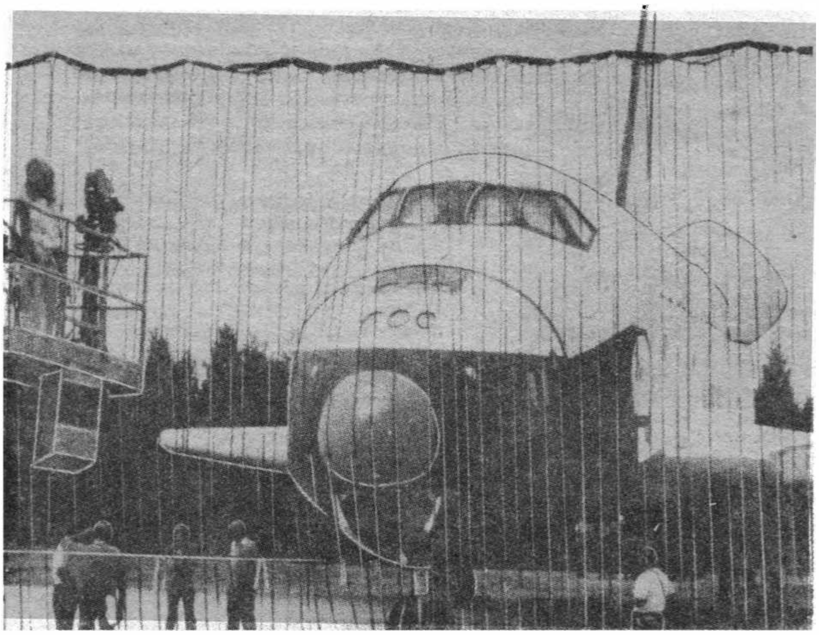
The launch for the Mars Observer mission has been slipped two years by NASA from the originally planned launch date in August 1990, ***writes Dr. W.I. McLaughlin***. See ***Spaceflight***, July/August 1986, p. 316 for a description of the mission.

With this move, long under discussion, the launch dates for all of the approved planetary missions have been decided, and the date of return of the Shuttle to operational status becomes the principal source of uncertainty.

Project	Launch Date	Launch Vehicle	Prime Data Return Begins
Voyager	(8/77)	(Tital III-E/Centaur)	1989 (Neptune)
Magellan	4/89	Shuttle/IUS	1990
Galileo	10/89	Shuttle/IUS	1995
Ulysses	10/90	Shuttle/IUS	1994
Topex/Poseidon	12/91	Ariane 4	1992
Mars Observer	9/92	Shuttle/TOS	1993
CRAF (FY89 new start sought)	2/93	Titan IV/Centaur G-prime	1996

INTERNATIONAL SPACE REPORT

NASA Issues New Funding Challenge



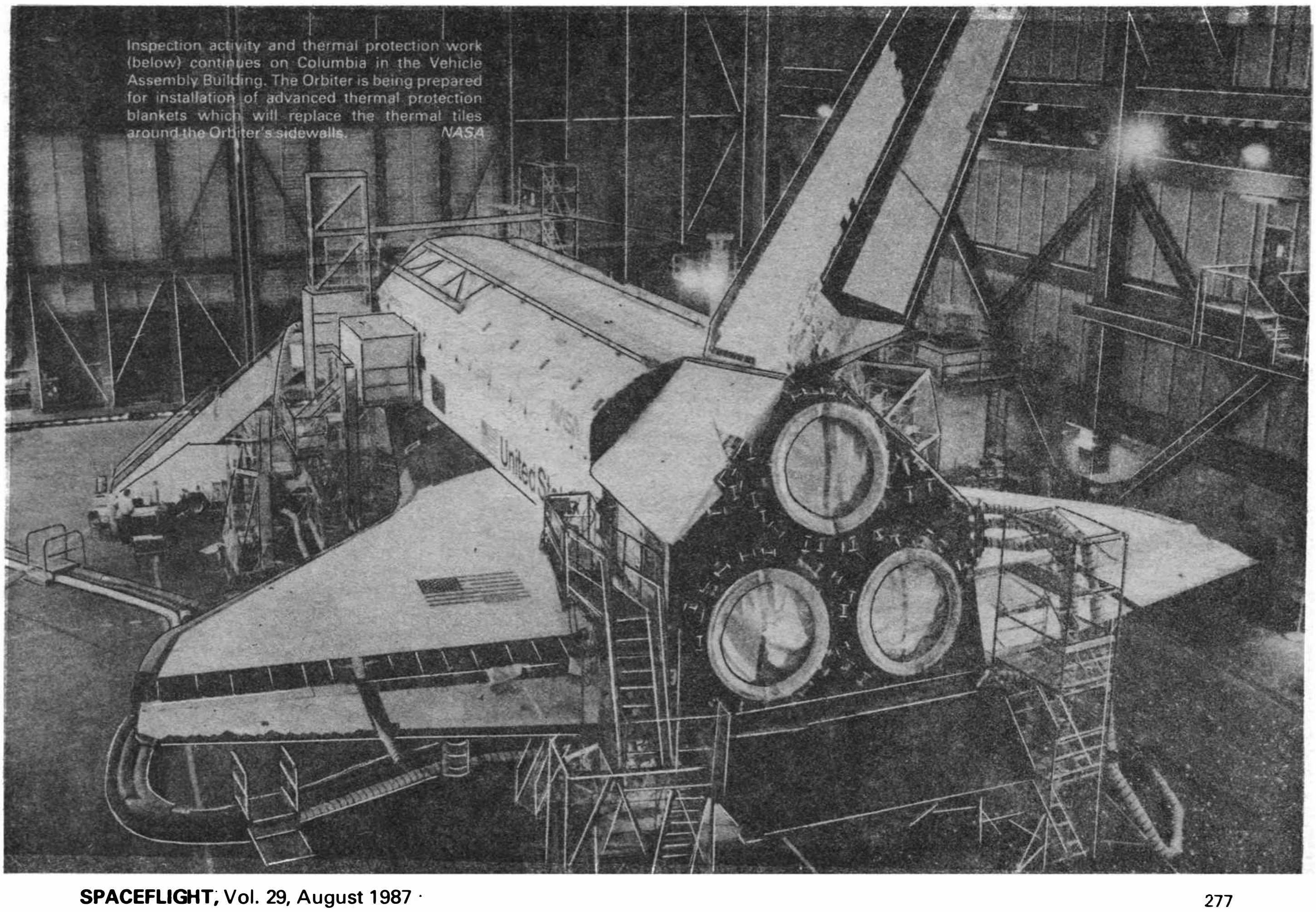
Enterprise was called back into service in June for validation tests of a proposed Shuttle emergency landing aid. The Orbiter, on loan from the Air and Space Museum, was slowly pulled through an arresting net (left). *NASA*

NASA reacted swiftly to the Soviet Union's successful launch of the Saturn V-class Energia heavy lift launcher on May 15.

A statement released a few days later said: "This success is additional evidence of the determined nature of the Soviet space programme. It is well-funded and makes steady progress, some of it spectacular. It is ambitious, especially with its plans in space science to explore Mars and Phobos. It is enlarging its space station and rapidly expanding its experience in manned space flight.

"While the Soviet Union was building its capabilities, the budget for the US space programme contracted dramatically following the Apollo programme. Today, budget considerations have forced us to go to a phased space station development programme and to postpone the time we will put the first element into operation.

"Numerous authorities on the subject agree that if the United States space programme is to remain ahead of the Soviet Union's, funding must rise to a new plateau so NASA can simultanously build and operate the Space Station, maintain a vigorous space science programme, develop advanced technologies and begin work on some ambitious new projects, such as establishing a permanent base on the Moon or beginning human exploration of Mars.



Inspection activity and thermal protection work (below) continues on Columbia in the Vehicle Assembly Building. The Orbiter is being prepared for installation of advanced thermal protection blankets which will replace the thermal tiles around the Orbiter's sidewalls. *NASA*

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST — 204

Robert D. Christy

Continued from the June 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

PROGRESS 28, 1987-23A, 17564.
Launched: 1114*, 3 March 1987 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Unmanned cargo vessel flying in support of the Mir space laboratory. It docked with Mir's rear port at 1243 on 5 March. On 26 March at 0507, it undocked, and at 0259 on 28 March its retro-rocket was fired to cause its re-entry into the atmosphere.
Orbit: Initially 185 x 254 km, 88.83 min, 51.64 deg, then manoeuvred to 344 x 369 km 91.61 min, 51.62 deg for docking with Mir.

COSMOS 1825, 1987-24A, 17566
Launched: 1504, 3 March 1987 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 633 x 664 km, 97.76 min, 82.54 deg

COSMOS 1826, 1987-25A, 17577
Launched: 1025, 11 March 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 354 x 416 km, 92.30 min, 72.88 deg.

COSMOS 1827-1832, 1986-26A to F, 17582-17587
Launched: 1317, 13 March 1987 from Plesetsk, possibly by F-2.
Spacecraft data: Not available.
Mission: Single launch of six satellites, possibly to provide tactical, point to point communications for troops or units in the field.
Orbit: 1385 x 1412 km, 113.81 min, 82.57 deg (lowest), 1411 x 1416 km, 114.14 min, 82.58 deg (highest)

COSMOS 1833, 1987-27A, 17589
Launched: 0837, 18 March 1987 from Plesetsk, possibly by D-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 849 x 852 km, 101.98 min, 71.02 deg.

RADUGA 20, 1987-28A, 17611
Launched: 0354, 19 March 1987 from Tyuratam by D-1-e.
Spacecraft data: Probably similar to the Gorizont satellites, being a stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links within the USSR.
Orbit: Geosynchronous above 85 deg east.

PALAPA 5, 1987-29A, 17706
Launched: 2212, 20 March 1987 from Cape Canaveral AFS by Delta 3920.
Spacecraft data: Cylindrical, spin-stabilised vehicle, with length about 6.5 m and diameter 2 m. The mass is about 700 kg.
Mission: Indonesian domestic communications satellite
Orbit: Geosynchronous above 113 deg west.

KVANT, 1987-30A, 17845
Launched: 0006, 31 March 1987 from Tyuratam by D-1.
Spacecraft data: Cylindrical shape, with maximum diameter 4.15 m, and length approximately 13 m (including the service module). The Section left attached to Mir measures 6 m in length and has a mass of 10.6 tonnes.
Mission: First add-on module for the Mir space laboratory, Kvant contains principally the international 'Roentgen' high energy physics observatory. After a docking failure on 5 April, Kvant attached itself to Mir's rear port at 0036 on 9 April. The Mir crew had to go outside on 11 April to clear an obstruction in the docking unit in order to complete the hermetic seal between Mir and Kvant. At 2218 on 12 April, Kvant's 10 tonne service module (now designated 1987-30C) undocked, leaving a new docking port available for further visiting craft.
Orbit: Initially 171 x 300 km, 89.16 min, 51.63 deg, then manoeuvred to 344 x 363 km 91.57 min, 51.63 deg for docking with Mir.

COSMOS 1834, 1987-31A, 17847
Launched: 0350, 8 April 1987 from Tyuratam by F-1.
Spacecraft data: Cylindrical, probably about 7 m long and 2 m diameter, equipped with solar cell panels and with a mass around 5000 kg.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 404 x 418 km, 92.80 min, 65.04 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1835, 1987-32A, 17849
Launched: 1145, 9 April 1987 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period, it re-entered the atmosphere on 4 June after 56 days.
Orbit: 172 x 344 km, 89.68 min, 64.76 deg, manoeuvrable.

COSMOS 1836, 1987-33A, 17876
Launched: 0620, 16 April 1987 from Tyuratam by A-2.

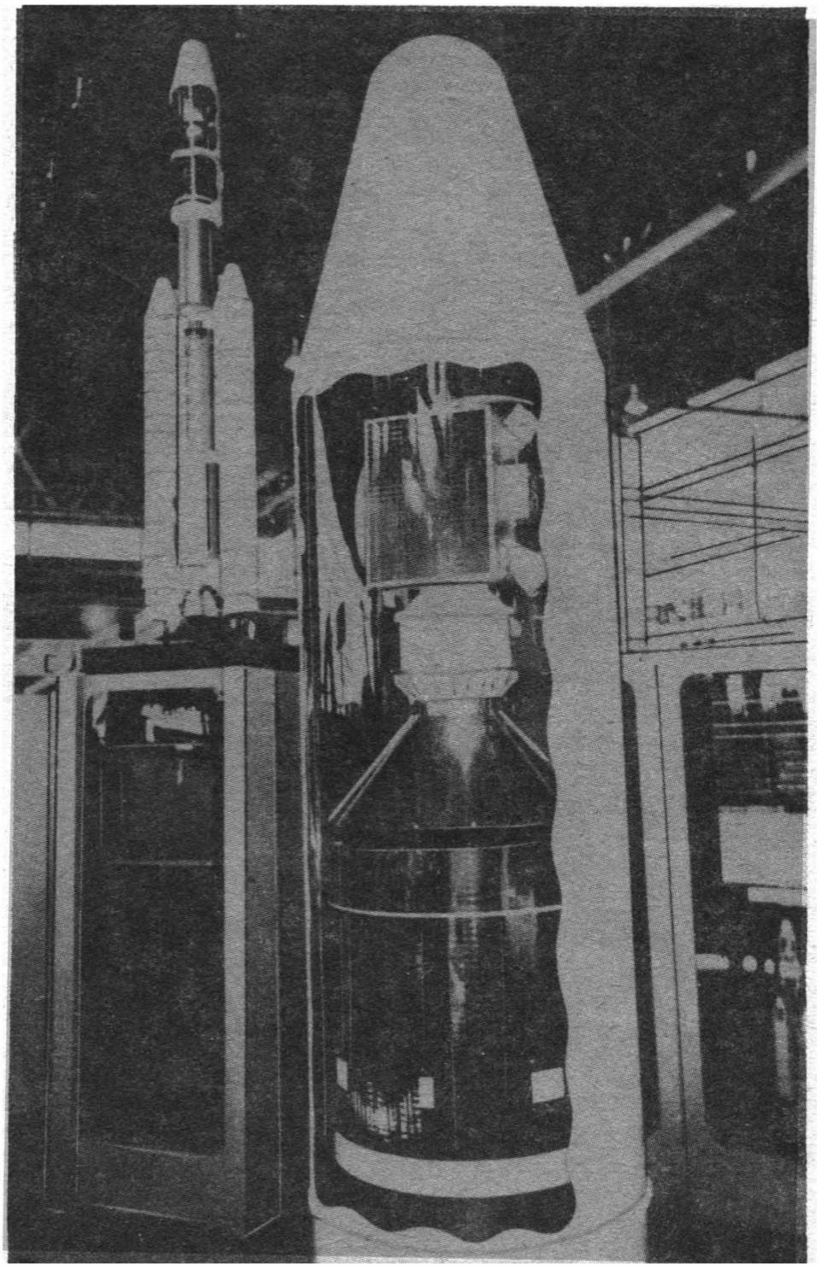
INTERNATIONAL SPACE REPORT

Spacecraft data: Possibily based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 213 x 288 km, 89.53 min, 64.80 deg, manoeuvrable.

PROGRESS 29, 1987-34A, 17878
Launched: from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Unmanned cargo vessel flying in support of the Mir space laboratory. It docked with Kvant's rear port at 1705 on 23 April. On 11 May at 0310, it undocked and at 0259 on 28 March and its retro-rocket was fired to cause its re-entry into the atmosphere.
Orbit: Initially 188 x 238 km, 88.70 min, 51.63 deg, then manoeuvred to 343 x 363 km 91.57 min, 51.63 deg for docking with Mir.

COSMOS 1837, 1987-35A, 17880
Launched: 0910, 22 April 1987 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 6 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 226 x 247 km, 89.30 min, 82.33 deg

COSMOS 1838-1840, 1987-36A-C, 17902-17904
Launched: 1240, 24 April 1987 from Tyuratam by D-1-e.
Spacecraft data: not available.
Mission: Intended cluster of three, GLONASS navigation satellites which were left in a useless orbit by a failure in the launching rocket's upper stage.
Orbit: 191 x 17145 km, 306.22 min, 64.68 deg (lowest), 191 x 17540 km, 312.19 min, 64.83 deg (highest).

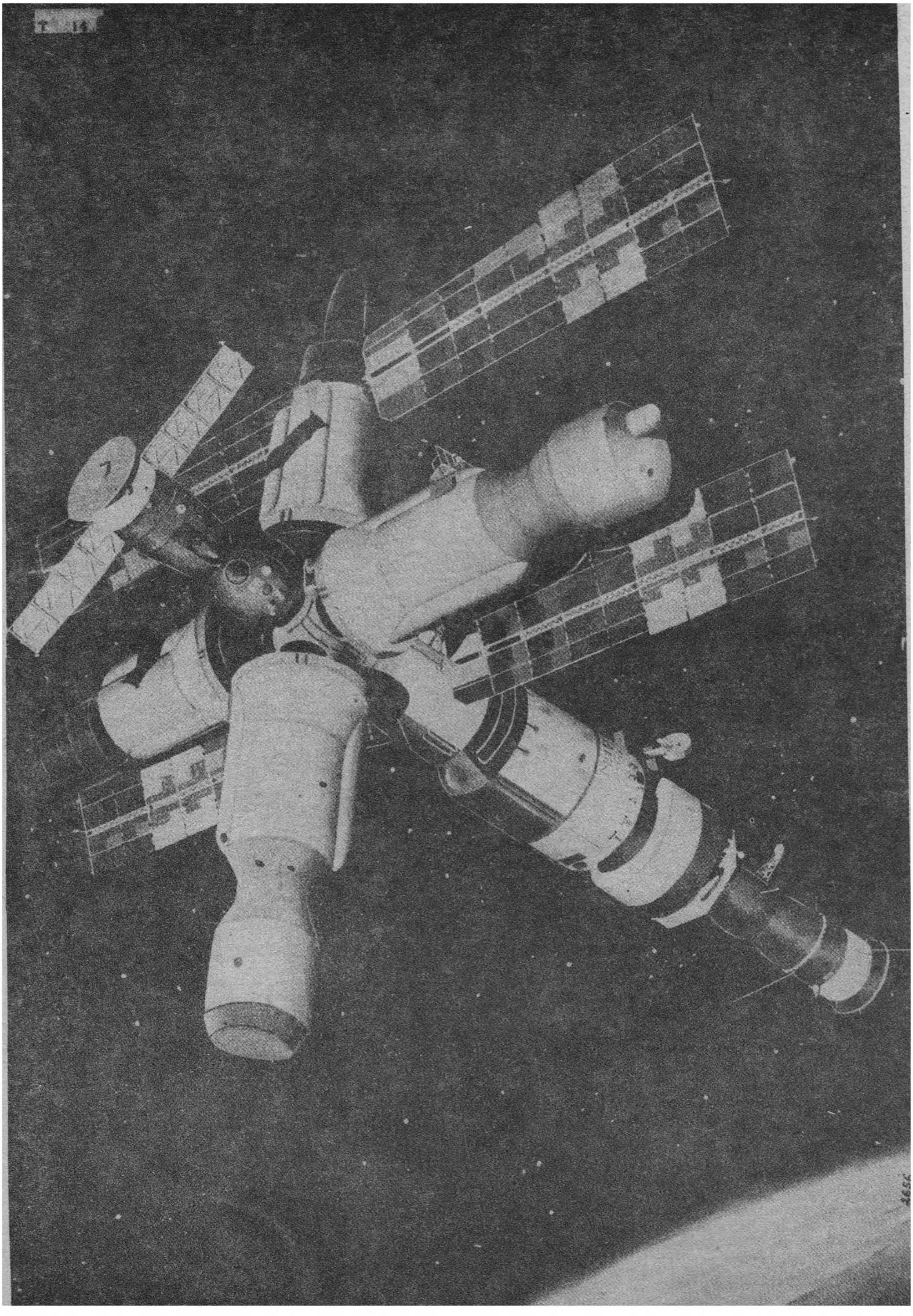


Commercial communications satellites will be launched aboard the Martin Marietta Titan 3 rocket starting in 1989. It will be capable of orbiting two satellites per flight to low-Earth orbit. The picture above, taken at the Paris Air Show, depicts the larger four metre diameter payload fairing, with the rocket behind.
J.W. Powell

COSMOS 1841, 1987-37A, 17907
Launched: 1700, 24 April 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Materials processing in microgravity, recovered after 14 days.
Orbit: 218 x 381 km, 90.52 min, 62.89 deg.

COSMOS 1842, 1987-38A, 17911
Launched: 0001, 27 April from Plesetsk, by A-2 or F-2.

Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 634 x 666 km, 97.80 min, 82.51 deg.



SOVIET SCENE

Mir · Soviet/Syrian Crew · Energia

World space activity continues to be dominated by the Soviet programme as only a glance at the launches listed on pages 278 and 279 so clearly shows. Current interest in Soviet manned spaceflight has been heightened by the July 22 launch of a joint Soviet-Syrian crew to be the first visitors to join long-stay cosmonauts Yuri Romanenko and Alexander Laveikin at the Mir space station. Recent activities at Mir are reported in this issue by *Neville Kidger* beginning on p. 282.

The new openness of the Soviets about their space programme, which has been widely welcomed, was in evidence at the Paris Air Show covered by our report beginning on p. 268. The long-awaited first launch of their Heavy Lift Launcher called Energia (Energy) on May 15 was subsequently well publicised. These trends augur well for international cooperation in space and an expanding interest by the Soviets in space commercialisation. Our first report of the Energia launch (*Spaceflight*, July 1987, p.5) is now updated by *Neville Kidger* who states that launch time on May 15 was 1730 GMT (not 1750 as previously reported).

He writes: The two-stage carrier rocket, with a launching mass of over 2,000 tonnes, is capable of placing over 100 tonnes into a low-Earth orbit. The first stage consists of four strap-on liquid-fuelled boosters each having one engine fuelled by an oxygen/kerosene combination.

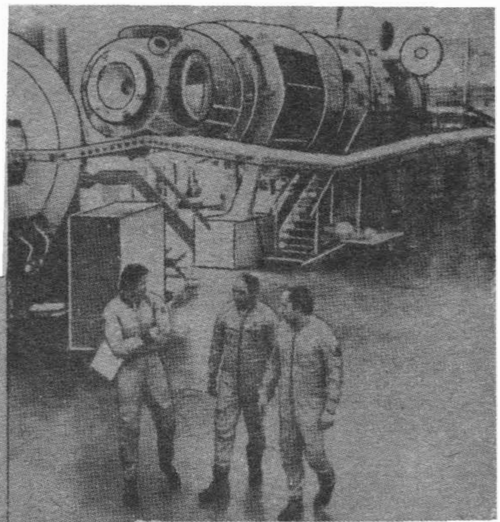
The central block second stage, a large liquid-fuelled rocket with four engines powered by a liquid oxygen/liquid hydrogen combination, is the first acknowledged use of such propellants by the Soviets.

Both stages ignite at launch with a combined thrust of some 4,000 tonnes. The first stage is discarded at an as yet unspecified time and the second stage continues burning to orbital height. The Soviets may have adopted the tactic used by the US for its Shuttle launches where the large External Tank, which Energia's second stage closely resembles, is cast off just before the Shuttle fires its own engines to place the spacecraft into orbit. The ET burns up in the upper atmosphere and any debris falls into the Indian Ocean. The Energia second stage fell into the Pacific in a similar fashion after delivering a payload to a designated point in space where its own engine, which failed, should have been ignited to place it into orbit.

US spy satellites in geostationary orbit saw the thermal signature of the satellite, (a side-mounted, pencil-shaped, black object) as it burned up in the atmosphere for "an unusually long period of time". It was an "intense", hot object which the US analysts regard as indicating the mock-up to be quite complex rather than simply a mass model of a satellite.

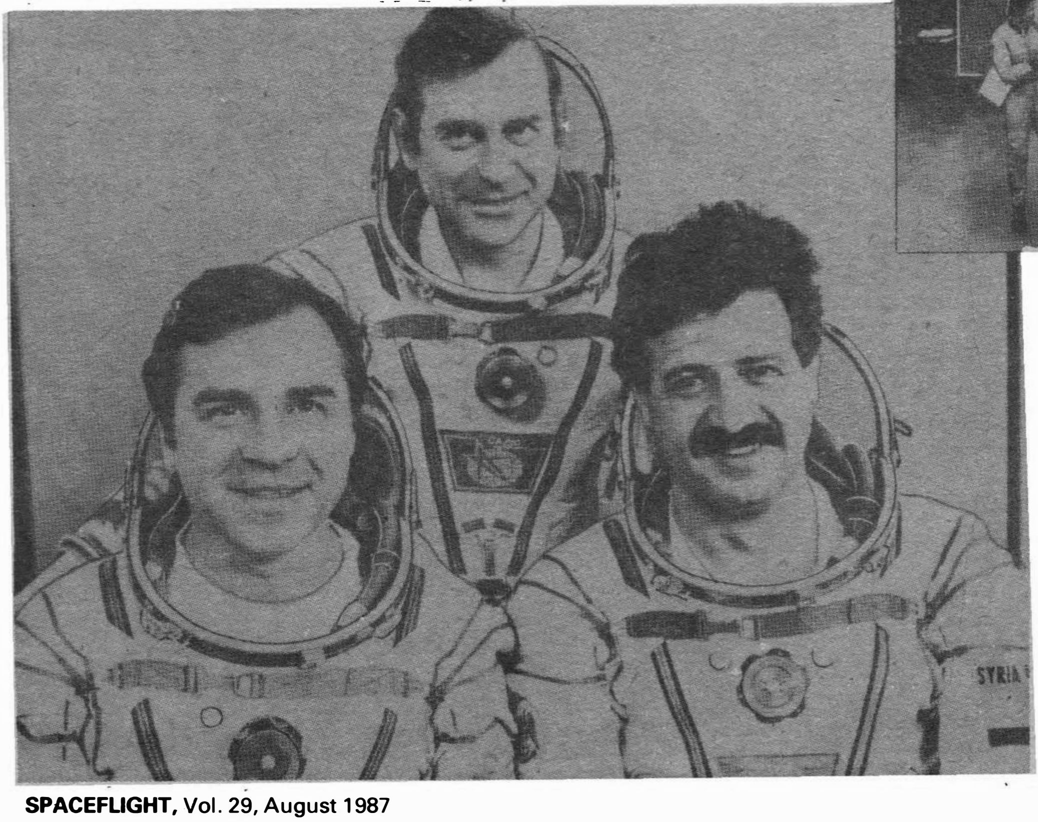
The Soviets have also said that the uses of the booster are wide and will include placement of large mass satellites, modules, orbital station or space shuttle into orbit. One specific use will be the creation of "operational assembly complexes ... a type of mooring for the assembly of ships, for their repair and refuelling."

*On p 285 **Tony Lawton** reviews the new technical features of Energia, which he describes as 'a completely new tool in the Soviet space workshop'*



Above: The back-up crew of the July 22 Soviet-Syrian space flight. On the right of the group is Mission Commander A. Y. Solovyov and on the left is Flight Engineer V.P. Savinykh with Syrian Researcher-Cosmonaut Munir Khabib in the centre. In the background is the Mir space station while installed at its checkout facility.
Novosti

Left: An artist's impression of the Mir configuration by Lucien van den Abeelen, who recently wrote for ***Spaceflight*** (May 1987, p.184) on Mir Dockings and Operations



Left: The crew of the July 22 Soviet-Syrian space flight. On the right is Syrian Researcher-Cosmonaut Mohammed Faris. The Soviet crew members are Mission Commander A.S. Victorenko and Flight Engineer A.P. Alexandrov in the centre.
Novosti

SOVIET SCENE

MIR MISSION: Third Solar Array Installed

by Neville Kidger

Two EVAs, on June 12 and 16, have enabled cosmonauts Romanenko and Laveikin to instal a third solar array on Mir thereby increasing its power to well above the 10 kW provided by the station's original two arrays. The new array was carried up to Mir onboard the Kvant module launched on March 31.

During the spacewalk on June 12, which lasted 1h 53m, the cosmonauts attached the two panels of the array and associated structure to the Mir complex. On June 16 the panels were deployed by unfolding them along the new support structure and then connected electrically to the station's internal system.

The two EVAs of June 12 and 16 are the second and third to be carried out at Mir. The first, on April 12, which had not been pre-scheduled, arose from the initial failure of the Kvant module to dock firmly with Mir.

The activities of the Mir cosmonauts subsequent to Kvant's firm docking are covered in the following report.

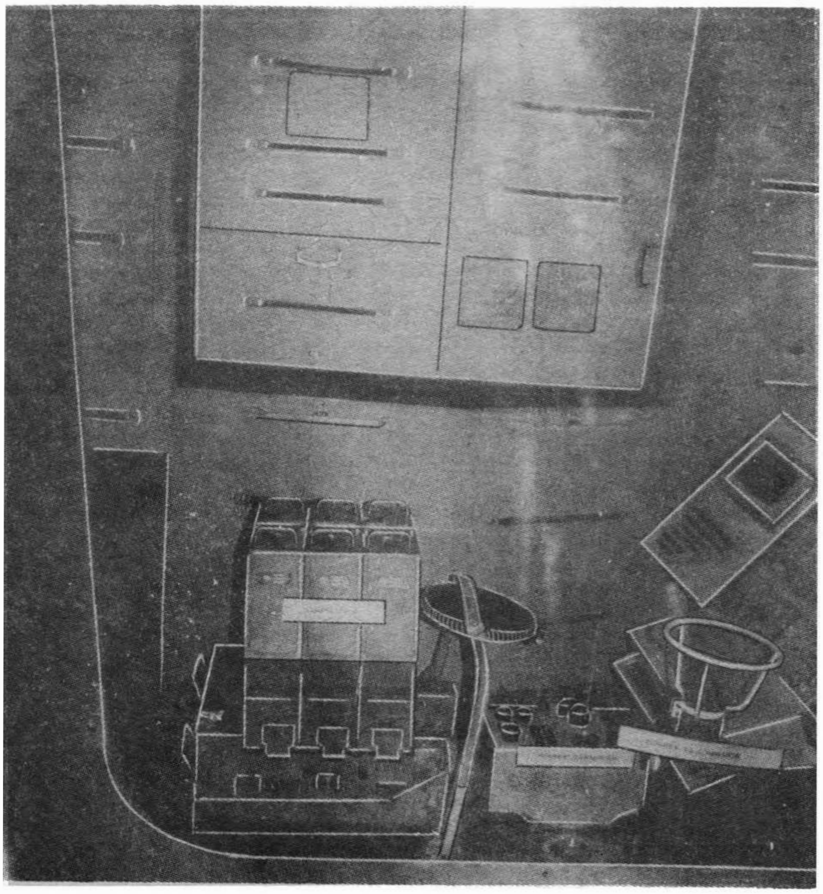
Kvant in Orbit

At 0006 GMT (all times GMT) on March 31 a three-stage Proton carrier rocket lifted off from the Baikonur Cosmodrome bound for near-Earth orbit. From an initial low orbit the astrophysics module and its engine block were to be manoeuvred to a docking with the rear port of the Mir base station unit on April 5. The length of the autonomous flight was longer than for the smaller Soyuz TM and Progress crafts so that much less fuel would be consumed.

The Kvant was equipped with the Igla (needle) rendezvous system to approach the station. The rear unit of Mir is equipped to accept either the Igla or the more advanced Kurs system which is used by the Soyuz TM manned spacecraft. The Kvant module was originally intended to dock with the Salyut 7 station but was delayed and so slipped to Mir.

During the period of the extended approach to Mir the two cosmonauts on the station, Yuri Romanenko and Aleksandr Laveikin (call-sign Taimirs), who had been in space for almost two months, were engaged with processing activities on the 136 kg Korund furnace and the PION-M multi-purpose physics module which weighs over 41 kg. On the actual day of docking with Kvant the men were on a rest day and were in the Soyuz TM-2 spacecraft with the hatches closed.

'nterior of Kvant showing the control station and MKF-6M camera installed in the "floor"



Docking Problems

Kvant "saw" the Mir base unit at a distance of some 17 km. The station was to be passive in the docking with all the manoeuvres to be performed by the engine block of Kvant. By the time the module was some 500 metres from the station the Control Centre had extended the docking probe of the module and a TV camera on the module was activated showing the station's on-board display on the screens of the controllers.

At a distance of 200 m, just minutes before the scheduled time of docking, Mission Director Valeri Ryumin radioed up to the two cosmonauts that he was receiving information that the lock-on of the rendezvous system had been lost and that the module had begun to drift. He asked Romanenko to go to the airlock and describe what he saw.

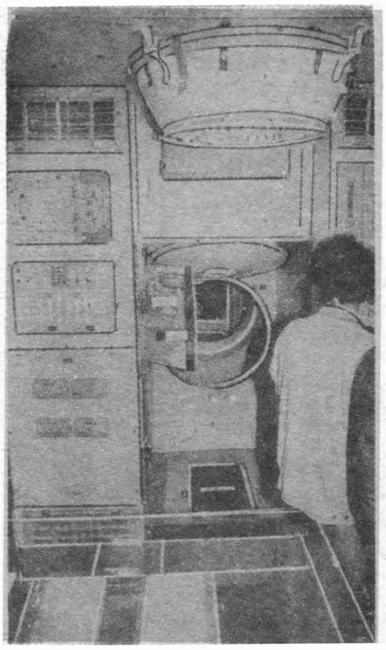
The commander said that he could see the Kvant module passing by (the UK Kettering Space Observer Group tapes of the event show that the miss distance between Mir and Kvant was about 10 m, according to reports) and that it was rotating slightly and drifting away. Despite the apparent close collision between the two vehicles the Soviets officially expressed no concern about it.

Ryumin told Romanenko to "stay calm" and that the engineers were to study the telemetry and come up with a new solution. For the next days the two cosmonauts spent time on routine maintenance, medical tests and activating the Kvant module.

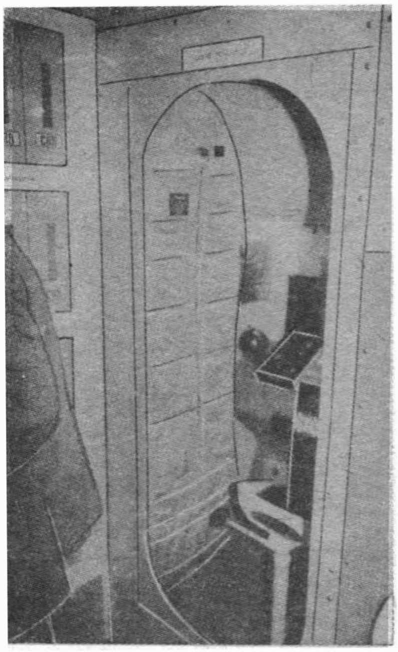
On April 6 a press conference was called at the Control Centre by Glavkosmos. Valeri Ryumin told the multinational team of reporters that the controllers had been "especially cautious" about the parameters allowed for the docking manoeuvre. He admitted that the controllers might have overdone the caution but that the problem was understood and the docking would be attempted again. There was fuel for many attempts to dock, the ex-cosmonaut said.

The correspondents were allowed to interview the cosmonauts via TV during two communications sessions. Romanenko said that he felt the optimal duration of space flights was three

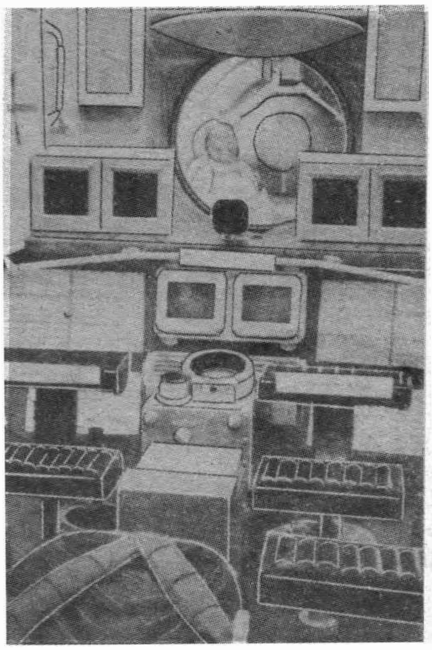
SOVIET SCENE



Main working area and hatch leading to Kvant module.



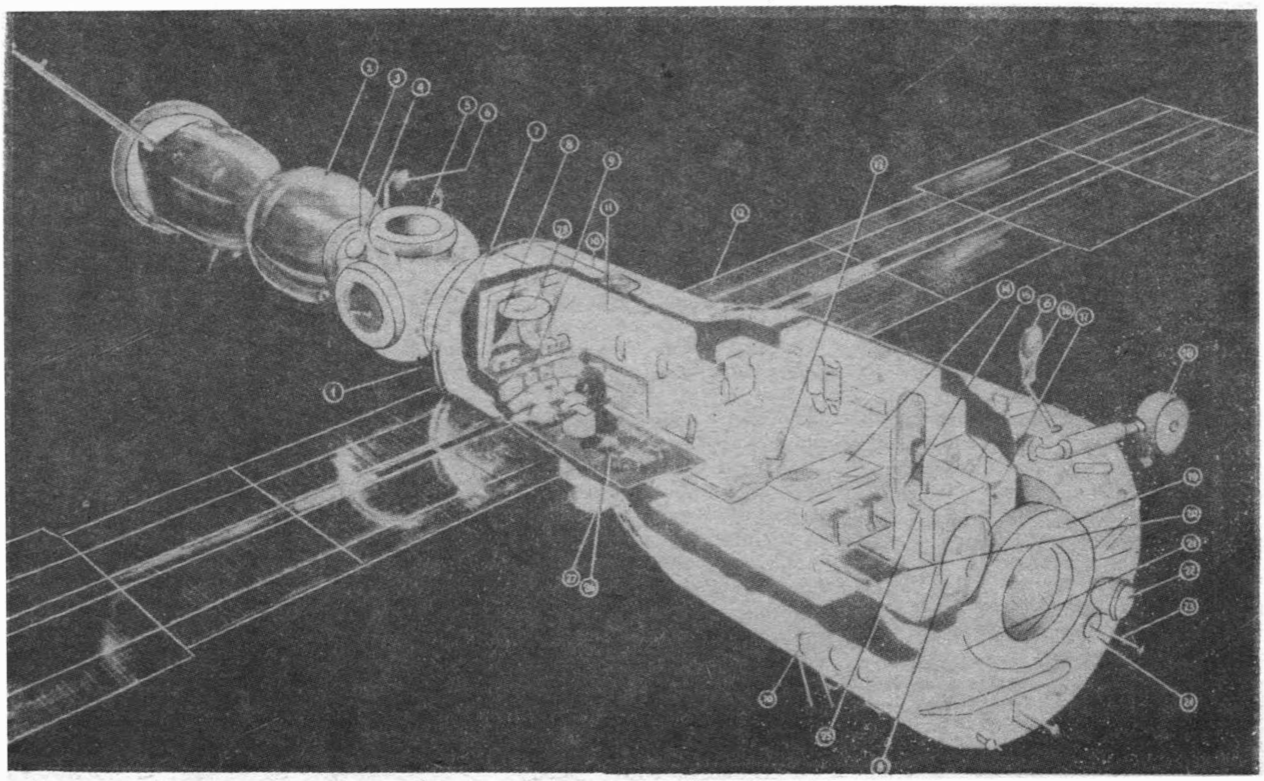
Cosmonaut's personal "cabin".



Central control post and hatch leading to main docking unit.

Pictures J W Powell and C.A Simpson

Cut-away view of Mir showing: *1. Base block. 2. Docked spaceship. 3. Adaptor module 4. Manipulator pocket. 5. Side docking units. 6. Docking systems' antenna 7. Working module. 8. Working module's hatch. 9. Central control post 10. Handrails. 11. Detachable panels of the interior. 12. Solar Cells. 13. Bicycle ergometer. 14. Working table. 15. Individual cabin. 16. Bathroom. 17. Wash-stand 18. Satellite-communications antenna, 19. Axial docking unit. 20. Track simulator. 21. Air-lock chamber. 22 Engine with a roof. 23. Target. 24. Engine accessories compartment. 25. Hatch lid. 26. Viewport. 27. Viewport blend.* Novosti



or four months but said that it was no secret that their flight was to be a long one (one French source has said that the crew will return to Earth in December 1987).

Laveikin, who is making his first flight, admitted that it had taken him three to five days to adapt physically to weightlessness, with the psychological adaptation process taking about a month.

It was later revealed that the controllers had identified the problem with Kvant's approach system within 24 hours and had found a solution. Another docking attempt was scheduled for the night of April 8.

At 2000 that night the cosmonauts again transferred to Soyuz TM-2 and donned their spacesuits.

This time the approach was smooth

SOVIET SCENE

and contact was made at 0036 April 9. However, as controllers tried to make the docking firm it became apparent that the docking probe had only penetrated some 365 mm into the Mir unit. Mir and Kvant then moved out of the radio visibility zone of the Soviet Union and contact was lost (the geostationary satellite network that Mir has the capability to use is not functioning because the only one of the three relay satellites launched to date for the system, Cosmos 1700, has failed and drifted off station).

On the next orbit the cosmonauts used an externally mounted TV camera to try and see what had prevented the hard docking. They were unable to see anything and it was quickly apparent that the only solution would be to go outside and manually examine the docking system.

First Mir EVA

Romanenko was involved in the first EVA of the Salyut programme when, in December 1977, he and Georgi Grechko had donned space suits and opened the front docking unit hatch to examine the face of the unit to look for any possible damage which had been caused by the Soyuz 25 spacecraft when that ferry craft had failed to achieve a hard dock in October 1977. Now, the veteran cosmonaut was to participate in the first EVA of the Mir era for the same reason, to examine a docking unit.

At 1941 on April 11 the hatch of one of Mir's four radial docking units was opened and the cosmonauts floated out. It was revealed by a TV commentator covering the EVA that just before the opening the pressure of Laveikin's suit had dropped as he switched from one system to another. The cosmonaut found that he had not selected the correct position for a switch on his suit. The commentator said that for about 10 seconds "my hair stood on end". Viktor Savinykh, who was also commenting, said that the crew had quickly understood the problem and rectified it.

The live TV relay of the early part of the EVA contained no TV from space "because (the cosmonauts) do not have sufficient hands (to carry cameras)". Instead, FCC screens showed two support cosmonauts in the hydrotank at Star Town as they practiced the procedures for crawling along the length of Mir's 13 metre length to the edge of the aggregate section where the cosmonauts could look down at the docking unit.

In space, Laveikin radioed that he could see "some white object" in the docking unit and asked the controllers to command the probe to extend and pull the two space vehicles apart. FCC told him to remove the object if there was no risk of injury to himself.

Laveikin used tools passed to him by Romanenko and managed to pull out the object which was a twisted piece of cloth (later speculation was that it had either been dropped in the docking unit when the Progress 28 cargo spacecraft had been loaded up or even that the cloth had been left on the Kvant before its launch).

FCC commanded the Kvant's probe to retract drawing the two space vehicles together with an applied force of some 20 tonnes and the docking was made secure and hermetical. The mission had been saved, to the relief of all involved. Romanenko and Laveikin returned to the airlock of Mir and closed the hatch after an EVA which had lasted three hours 40 minutes. Most of the EVA had taken place during the early hours of April 12 in the USSR, which the country has celebrated as Cosmonautics Day since the flight of Yuri Gagarin in 1961.

The Soviets reported that the assembly was now some 35 metres long and had a weight of 51 tonnes. At 2018 on April 12 the engine block was commanded to undock from the rear of Kvant and flown into its own orbit. The undocking left Kvant's second docking unit exposed and the Soviets said that the unit could receive manned and unmanned spacecraft.

Working on Kvant

The two cosmonauts opened the hatch of Kvant the next day and began to open up its systems for operation. Inside the 40 m^3 laboratory area of the module, the Soviets later revealed, were a group of components for an additional set of solar panels which the Soviets had originally scheduled to be installed outside Mir by the cosmonauts in two EVAs in mid April. However the docking problems with Kvant were now delaying the EVAs.

The additional panels were needed to power Kvant's magnetically suspended gyroscopes. These will be needed to place the station in a "rough" pointing mode for the operation of the battery of X-ray telescopes of the Roentgen astrophysics payload. The gyros mean that the station does not have to expend fuel to achieve the pointing.

The Soviets revealed that the forthcoming EVA's would be performed with both the airlock compartment of Mir and the Orbital Module of the Soyuz TM-2 ferry spacecraft depressurised. The airlock itself did not have enough space to house both cosmonauts and the new solar panel assemblies. The panels will use an erection device similar to that used by cosmonauts Kizim and Solovyov on their two 1986 Salyut 7 EVAs when they tested a "Beam-Builder" device in open space for the first time.

The Soviets said that the EVAs were scheduled for the early part of May but by mid-May they had not occurred and the Soviets announced that they had been postponed until later. The presence of the panel elements in Kvant made the interior rather cramped initially.

Working with Kvant, the first order of priorities was the installation of a new control memory in the complex's computers. The addition of Kvant had shifted the centre of gravity of the complex and this altered all the algorithms for manoeuvring the complex. The Soviets had set aside much of May for the cosmonauts to practice the attitude control of the complex.

Another Progress Cargo Ship

On April 14 the two cosmonauts participated in a live TV show which was being broadcast in France. The exchange was the first time ever that live exchanges from orbit had been seen between a western European nation and a Soviet manned space station. The cosmonauts were shown film clips, pop videos and other items and they described their work.

The French cosmonaut Jean Loup Cretien is to make a second flight on a Soviet spaceship in 1988 and will make an EVA from Mir during a month-long mission on the station.

At 1514 on April 21 the Soviets placed another Progress cargo ship, number 29, into space and it docked with Kvant's rear docking unit at 1705 on April 23 to form the world's first four-spacecraft docking. The Soviets called the assembly a "train" in orbit and a Soviet TV commentator, showing pictures of the Soyuz TM-2/Mir/Kvant assembly from the approaching cargo ships said that the dream of Konstantin Tsiolkovski of settlement in orbit was coming true before the eyes of the viewers.

The cargo spacecraft delivered 138.5 kg of assorted scientific equipment, including some for the flight of the Soviet/Syrian crew. Also aboard was 275 kg of replacable equipment for Mir, 250 kg of foodstuffs, newspapers, letters and other cargo as well as the usual loads of fuel, air and water.

Refuelling of the complex was achieved, via piping contained in Kvant, prior to the May 1 holiday when the cosmonauts had a rest day and watched TV of the traditional parade in Red Square.

During the early part of May the cosmonauts began their control tests on the complex and conducted Earth observations of the USSR.

At 0310 on May 11 Progress 29 was jettisoned from the complex and commanded to destructive re-entry at an unspecified time the same day. The men continued with their technical work.

SOVIET SCENE

Energia – Soviet Super Rocket

by A.T. Lawton

Since the early 1980's Western analysts have speculated that a new heavyweight launcher capable of delivering payloads to low-Earth orbit of 100-150 tonnes was in an advanced stage of development. This speculation was confirmed on May 15, 1987 by the launch of such a vehicle and release of press pictures and television newsreels of the launch some 24 hours later. Those who have closely followed the development programme have had their ideas confirmed but a very close examination of the released data shows that the Soviets have possibly introduced some very advanced concepts to the new launch vehicle. This article outlines its salient features.

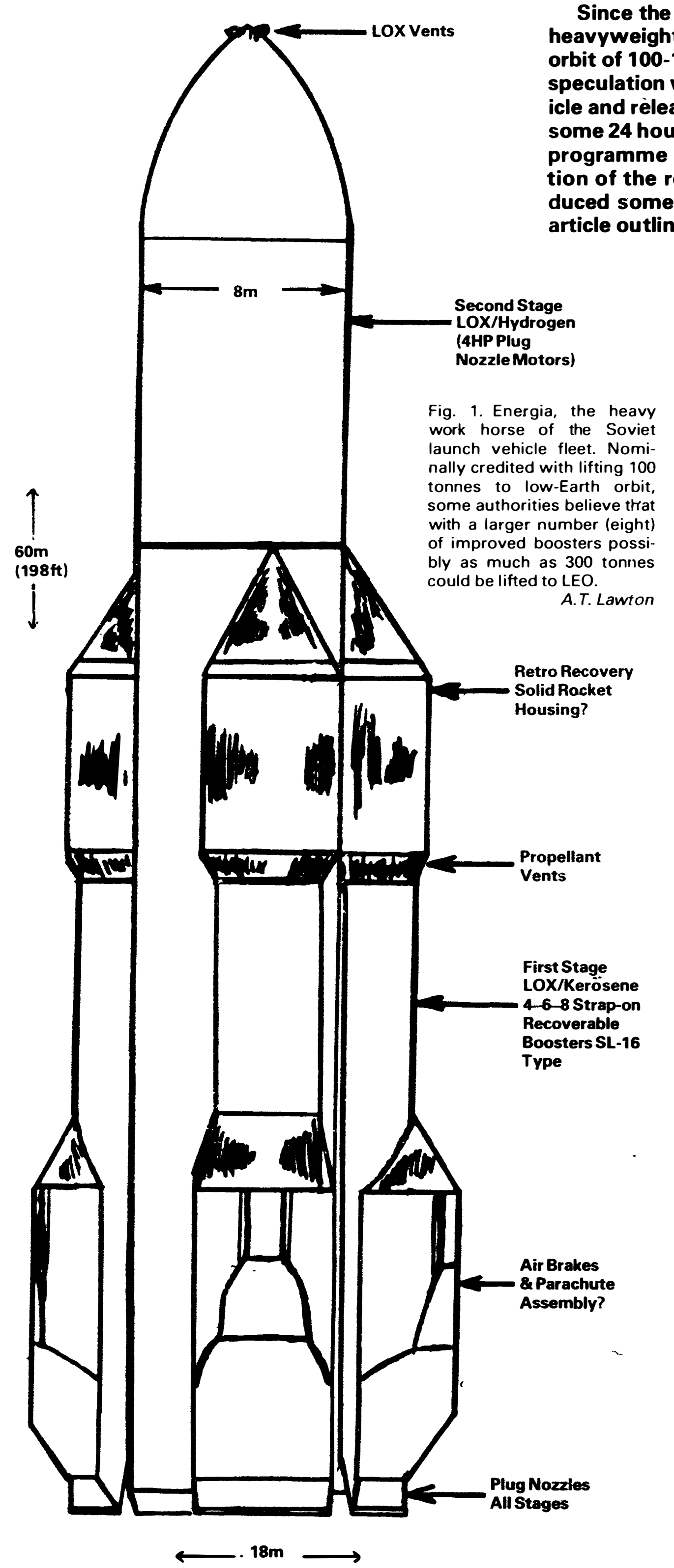


Fig. 1. Energia, the heavy work horse of the Soviet launch vehicle fleet. Nominally credited with lifting 100 tonnes to low-Earth orbit, some authorities believe that with a larger number (eight) of improved boosters possibly as much as 300 tonnes could be lifted to LEO.
A.T. Lawton

Energia

The new launch vehicle is officially named Energia (Energy) and careful scrutiny of television close ups show that it is a completely new configuration employing several novel features (see Fig. 1). The whole impression is of a vehicle with immense lifting capability and with several features which will allow it to enjoy a long life and performance stretch capability which is at least as great – if not greater – than the much used Soyuz A4. A measure of the performance increase of Energia is shown by the fact that in its present demonstrated form it is capable of lifting 100 tonnes to low-Earth orbit LEO). This represents about one third of the total present Soviet annual LEO payload. Put another way one Energia launch to LEO is equivalent to five Proton SL-13 or 15 Soyuz A4 launches. It must not be assumed however that such figures render the SL-4 and SL-13 obsolete. They will still continue to be used in tasks where they may be efficiently deployed.

Energia is thus a completely new tool in the Soviet Space Workshop. Its need has been demonstrated for a long time, and it is clearly intended to replace the ill-fated Type G whose disastrous career has been well documented in ***Spaceflight*** and elsewhere.

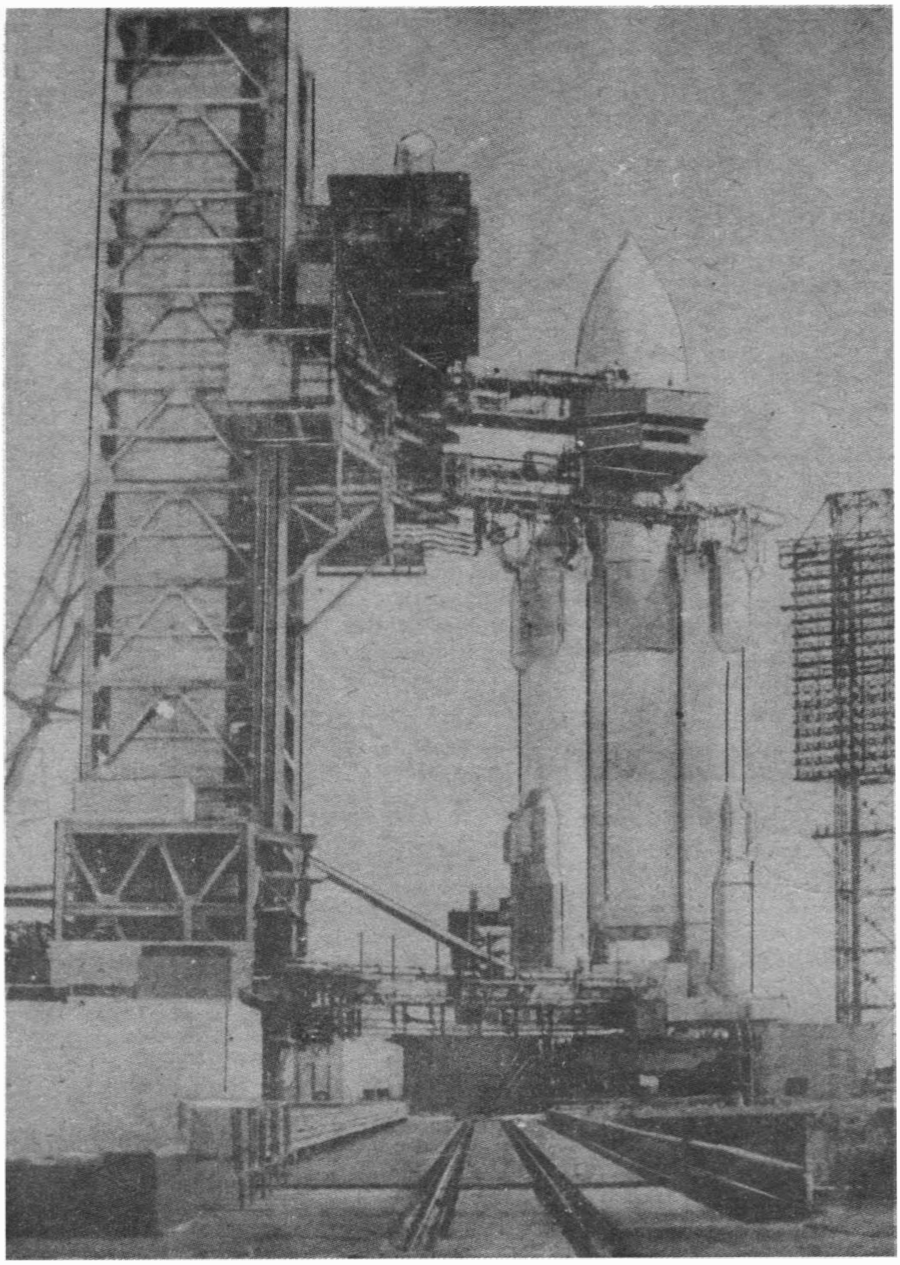
Need for Energia

It is clear that the Soviets learned many valuable lessons from the Type G failures and went right back to the drawing board to start again at the very beginning.

The basic specifications seem to have included the following:

1. Payload to LEO not less than 100 tonnes.
2. Full use to be made of the (then) new cryogenic fuels available – liquid methane or liquid hydrogen.
3. Liquid fuels and the controllability thereof to be retained for all stages.
4. All valuable items to be recoverable (within the design considerations of other parameters).
5. Emphasis to be placed on crew safety – the vehicle was to be designed as man rated – and large numbers of people could ultimately be carried as passengers in some planned payloads.
6. Speedy launch and re-launch capability with a minimum of highly skilled, trained (and expensive) personnel. If killed in an accident such people are not easily and simply replaced.
7. The whole vehicle to be as sturdy as possible.

SOVIET SCENE



Two of the Energia rocket's four strap-on liquid fuelled boosters can be clearly seen in this picture of the Heavy Lift Launcher at the Baikonur Cosmodrome.

These parameters completely ruled out any refinement of the Proton and Type G techniques and principles. It is also possible that the Soviets made two or more important further decisions at this stage:

- What are now known as Proton SL-12 and SL-13 would be scaled down versions of the Type G with reduced first stage capability. This has been more fully persued by Bond and Parfitt [1].
- None of the systems (payload excluded) associated with Proton and Type G would be man-rated.
- The originally projected Salyut stations would have to be scaled down to minimum essentials as a result of the lowered targets above.

This latter speculation arises from the surprise personally expressed by Soviet space correspondents when the dimensions of Salyut 1 (launched April 19, 1971) were first announced. They were expecting a much larger vehicle. However, no one will deny that the Salyût programme has accomplished much if not all of what was expected of it – and it has been successfully stretched as Salyut 6 and 7, and now Mir – and there appears to be room for still further design stretch, when even larger replacements are available.

It therefore seems reasonable to suppose that the scaled down Salyut/Mir programme has allowed the various Design Bureaux involved sufficient time to research and develop the necessary technology for a large, efficient, semi-recoverable launcher without compromising the essential acquisition of scientific knowledge and techniques required for 'Man in Space', and 'Man to the Planets' programmes.

If this is correct then we can expect a sudden burst of Soviet space activity on a much larger scale and at a rate which the West may find difficult to match. The US failed to exploit the potential offered by Saturn V, and recent estimates suggest a time lag of five to seven years before a vehicle comparable to Energia will be available in the West.

Energia Examined

Press details, pictures and television sequences enable many details surmised in Western circles between 1983 and 1987 [2,3] to be verified. In addition, a Glavkosmos team (visiting the US for the purpose of advocating the Proton SL-12 as a commercial satellite launch vehicle) were able to furnish further technical details.

Figure 1 establishes the proportions and approximate dimensions of Energia. It is a '1½' stage system employing a launch ignited core vehicle surrounded by four – six or eight liquid propellant boosters which are subsequently cast off and recovered down range. The core vehicle carries on burning and raises the combination to near orbital velocity. A small (by comparison) motor on the payload raises the 'delta Vee' to the required orbital injection velocity. This failed in the actual Energia test of May 15 and the payload plunged to a fiery end in the Pacific. Despite this setback the Soviet authorities judged the whole exercise to have been a considerable success and to have proved the validity of several concepts deemed essential to future planned programmes. I suggest that the failure of the payload motor system may parallel similar failures experienced with Proton launches a few weeks earlier.

Propellants used (according to press information) are as follows:

- Boosters – Liquid Oxygen and Kerosine.
- Core Stage – Liquid Oxygen and Liquid Hydrogen.

These statements are borne out by the colours of the flames visible in the evening launch of May 15.

In addition I would surmise that the

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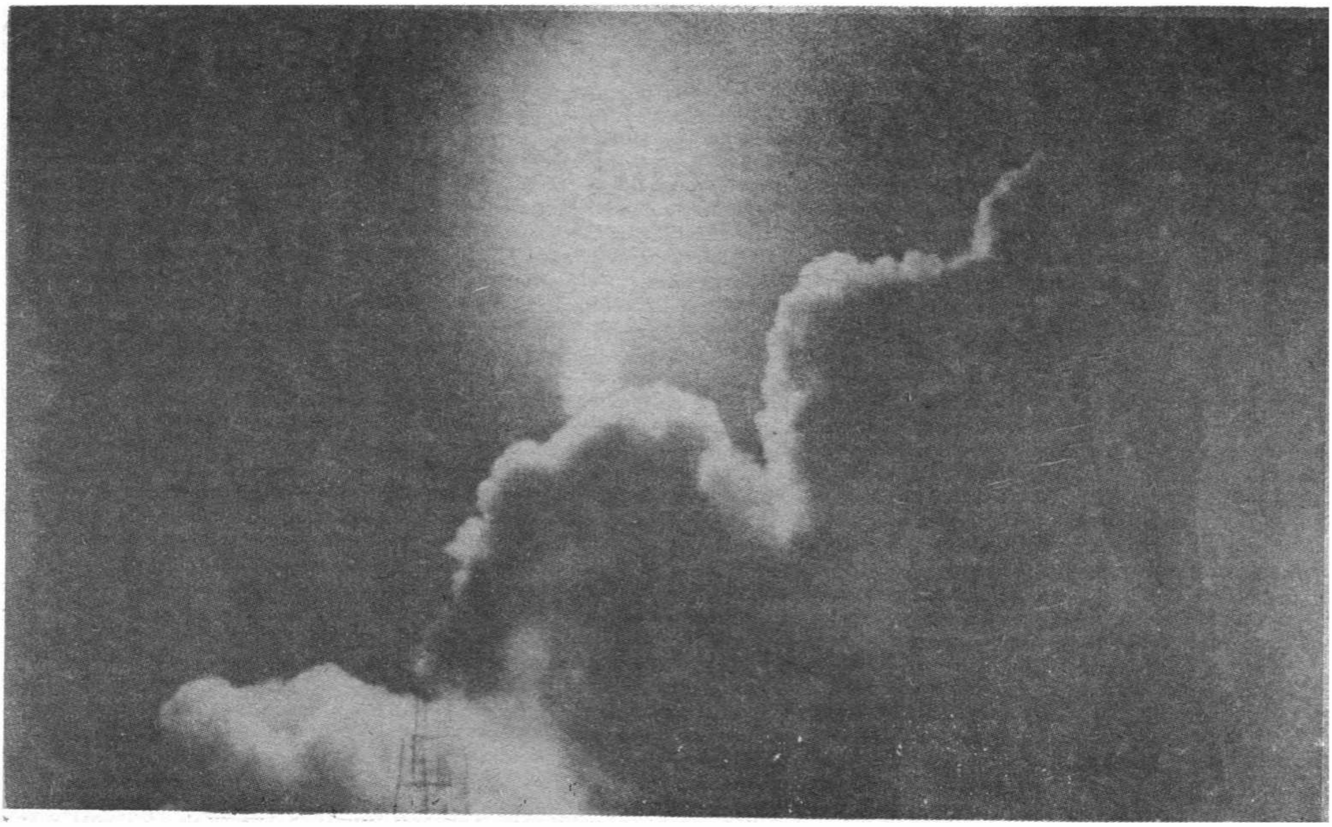


First launch of the Energia rocket lights up the sky over Baikonur at 1730 GMT on May 15.

payload motor probably used nitrogen tetroxide (N_2O_4) and hydrazine (UDMH) a hypergolic (self-igniting) combination used by the Soviets over the last 30 years or more.

All of the above would contribute to the high performance predicted for Energia but still better performance may be obtained from 'advanced motor design' using ultra high presssures for injection and combination.

Plug Nozzle Motors?

If the sketches and drawings of Refs 2 and 3 are examined, it is clear that the technical experts and artists cannot interpret the moderate resolution photographs obtained from satellites with sufficient accuracy – the nozzles appear to be too short and stubby for conventional bell mouth venturi design.

I would suggest that the whole configuration is better answered by assuming a plug nozzle assembly, with the "expansion nozzle" merely serving as a deflector shield to prevent flame interference effects damaging vital structures. Such deflector shields are simple, robust structures which are not heavily stressed in the same manner as is a bell mouth nozzle with pressurised coolant fuel circulating through it. For detailed comparison see Figures 2a and 2b. In the plug nozzle arrangement the coolant is pumped through the core of the motor – a much simpler and more reliable system.

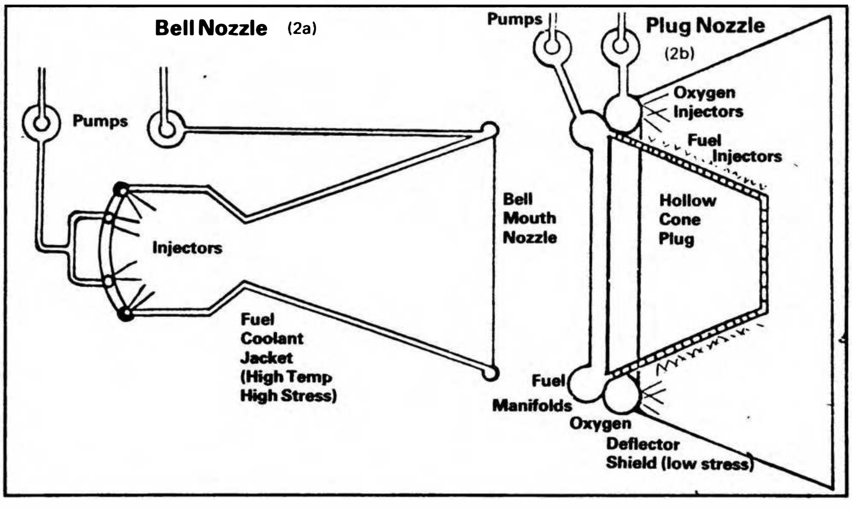
The plug nozzle motor is also much more robust – an asset which allows it to be operated at very much higher pressures than its more conventional counterpart. This in turn makes for a more efficient motor and pressures as high as 500-800 atmospheres may be involved.

At present, it is difficult to assess the specific impulse (SI) of either the first or second stages, but a shrewd guess would estimate above 380 seconds for the booster motors and above 485 seconds for the cryogenic core stage. These figures match or surpass those achieved by the US Shuttle, and if extra high pressure plug nozzle motors do feature in the Energia design then the Soviets are justified in claiming them as "advanced design propulsion units".

Booster Recovery Systems

The booster motors are also probably recoverable. Close examination of press photos and TV newsreels shows

Fig. 2. A Bell Nozzle compared with a Plug Nozzle. *A.T. Lawton*



SOVIET SCENE

Energia – Launch and Recovery Stages

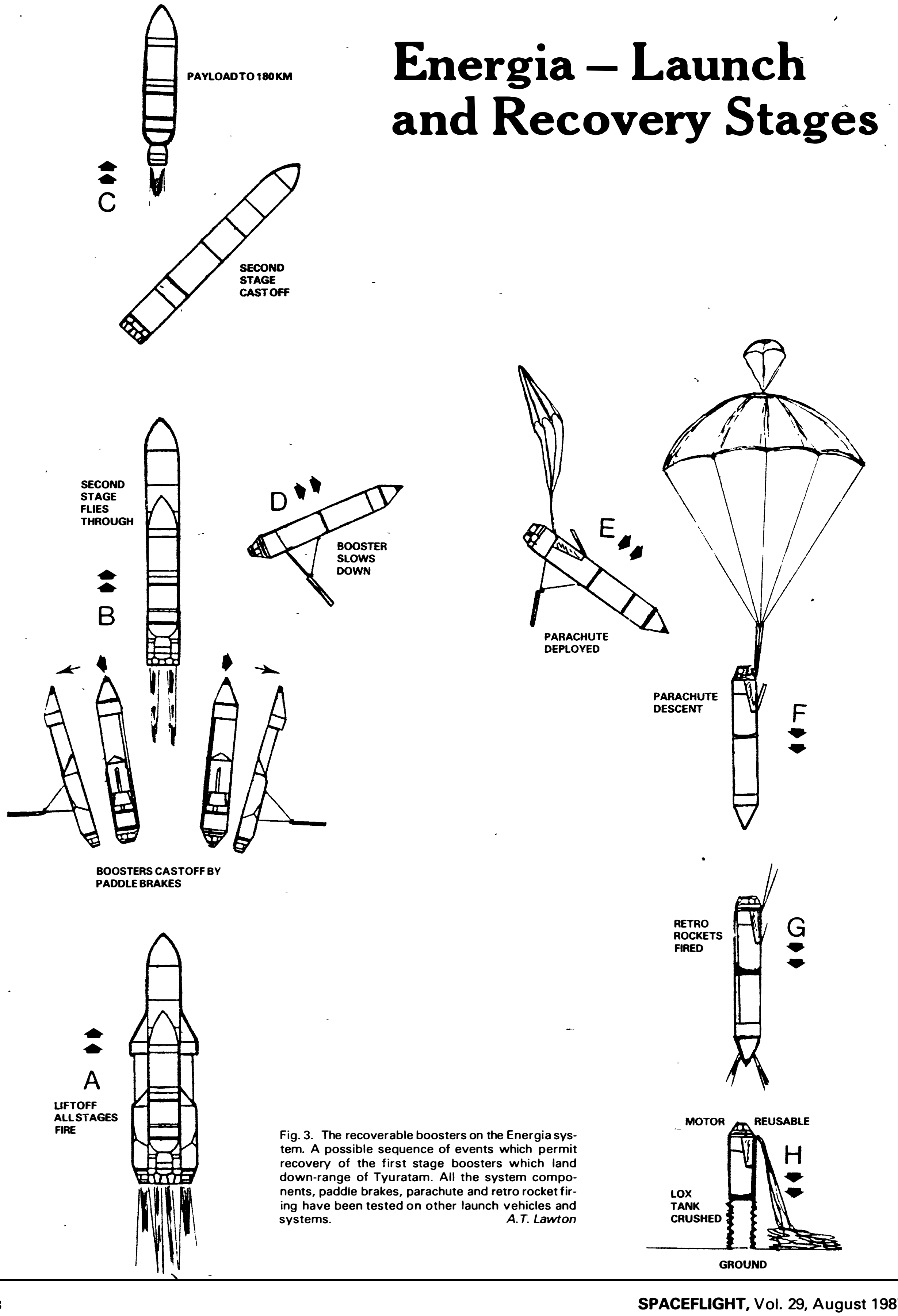


Fig. 3. The recoverable boosters on the Energia system. A possible sequence of events which permit recovery of the first stage boosters which land down-range of Tyuratam. All the system components, paddle brakes, parachute and retro rocket firing have been tested on other launch vehicles and systems. *A.T. Lawton*

SOVIET SCENE

a peculiar folded paddle shaped object at the base of each boost motor assembly. These objects bear a strong resemblance to the units (which are now known to be aerodynamic brakes) mounted on a standard Soyuz craft. Their function is to slow the spacecraft to a suitable speed for parachute deployment in an emergency abort situation. The concept has been thoroughly tested and tried, and used in anger when a fully crewed launcher exploded on its stand.

The paddles mounted on the Energia boost motors could be operated by a simple squib pyrotechnic device (Fig. 3b) and once opened, the air brakes are held open by aerodynamic forces. These forces are *symmetrical* about the whole assembly but *asymmetrical* about themselves. The action is therefore to pull the now dead boosters off the main body of Energia allowing the second stage and payload to proceed on to orbit (see Fig. 3b and 3c).

The four (or six or eight) "dead" boosters not only slow down, they also rotate until the paddle brake is at the top (Fig. 3d). At this stage it is assumed that a parachute is deployed as in Fig 3e and the booster plunges Earthward at a controlled rate. When it reaches a pre-determined height small solid rockets are fired by a proximity fuse (Fig 3f and 3g). This checks the descending booster body which drops onto its nose and forward body part. This contains the liquid oxygen tank which may be considered expendable. The tank crumples, which absorbs any residual energy, and the body remains upright with the expensive items (motors, pumps, turbines, and fuel metering equipment) undamaged and merely needing inspection, testing and checking before being attached to new tanks and sent into space again (Fig. 3h). The whole assumed sequence of events is shown in Fig. 3 sequences a to h.

The recovery of boosters as outlined above has not yet been confirmed, but the investment in advanced motors, pumps and turbines would have been so large (extending over a minimum of 20 years) that such recovery measures would be justified.

The fate of the second stage is not yet known but it would be possible to boost it into orbit as a separate entity from the payload, uncouple the motor complex – and bring the motors back in "Buran" the large Shuttle spacecraft.

The tanks could then be used as orbital constructional materials – already formed and tooled for multitudinal purposes. We must await developments.

First Trial Payload Failure

The first Energia trial of May 15 was not wholly successful – the payload stage failed to ignite and achieve orbit. At present the cause has not been revealed but it may be closely allied to similar failures which occurred recently in Proton launches.

The Energia-SLW Family

The present Energia as first seen by Western eyes must be regarded as a prototype of a whole new family of launch vehicles.

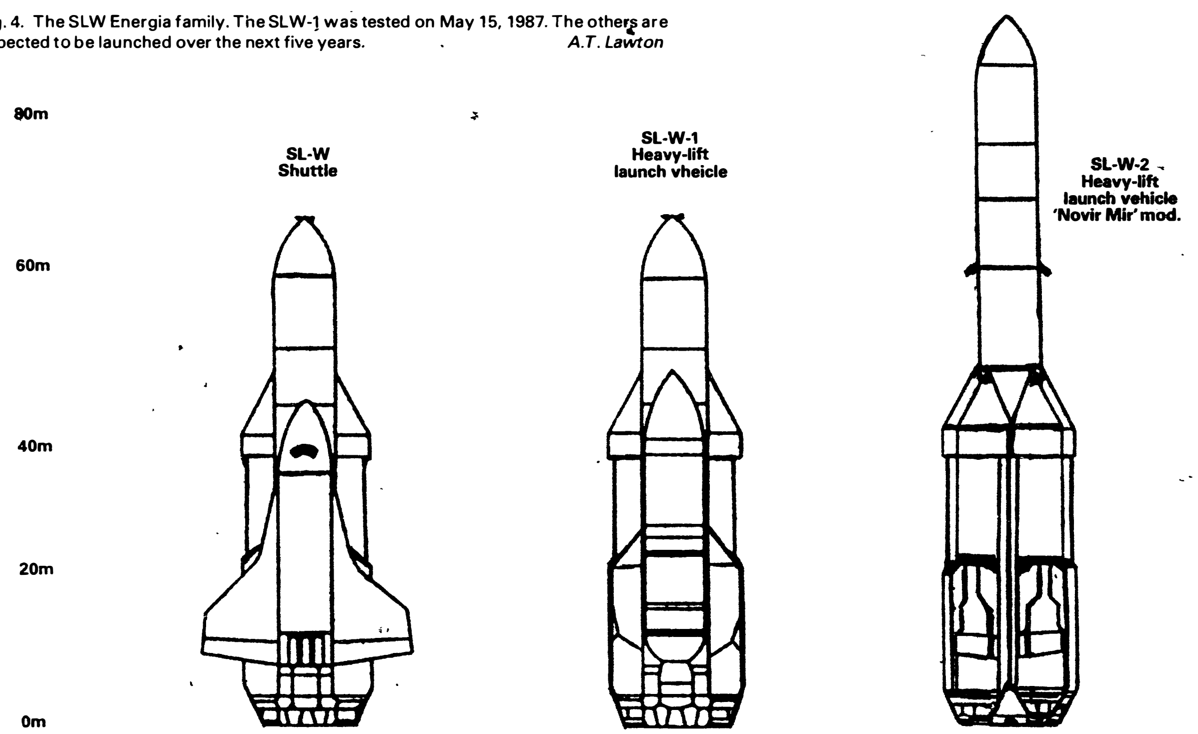
It is the vehicle intended for use with Buran and could well be easily adapted to evolve into a habitat similar to but larger than Mir which I have provisionally titled "Novir Mir" (New World). The various developments of this family are provisionally shown in Fig. 4. Further lifting capability might arise from using liquid methane instead of kerosene in the recoverable booster vehicles.

Conclusions

In this review article it is considered that the Soviets have at last got the Heavy Lift Launch Vehicle they aimed for 25 years ago. One of the major reasons for the delay was the need to be fully convinced that technical problems raised by using liquid hydrogen could be successfully solved. They also appear to have gone one stage further in developing motors whose design will steadily accommodate further improvements. They now seem ready to take the next real steps into space and walk on the highway to the Moon and planets.

References
1 Parfitt J Bond A "The Soviet Manned Lunar Landing Programme" *JBIS* Vol 40 No 5 pp 231-234 1987
2 *Soviet Military Power*, 1984 edition
3 *Soviet Military Power*, 1987 edition

Fig. 4. The SLW Energia family. The SLW-1 was tested on May 15, 1987. The others are expected to be launched over the next five years. *A.T. Lawton*



	SL-W Shuttle	SL-W-1	SL-W-2
Lift-off weight (kg)	2,000,000	2,000,000	3,000,000
Lift-off thrust (kg)	3,000,000	3,000,000	4,000,000
Payload to 180 km (kg)	30,000	100,000	160,000

Orbits for Amateurs with a Microcomputer, Vol.II

D. Tattersfield, Stanley Thornes (Publishers) Ltd., Old Station Drive, Leckhamption, Cheltenham, Glos. GL53 0DN. 1987, £16.95, 159pp.

Although the author has extended the range of methods described in Vol.1, his new work is largely independent of this.

Section 1 covers the standard cases of normal elliptical and parabolic orbits, including the more awkward cases of the elliptical orbit whose eccentricity is close to unity and the hyperbolic orbit. Section 2 applies the method of Gauss to an elliptcal orbit as a replacement of Laplace's method described in Volume 1. The method of Olbers, in which the orbit is assumed to be parabolic, is also included in this volume. Section 3 uses the method of Oppolzer, in which the variations of the elements of the orbit due to perturbations by the major planets are continuously obtained. Also included are computations relating to the orbits of meteor streams and of artificial satellites circling the Earth.

The programmes have been written in BASIC and should, therefore, by easily accomodated on most microcomputers. Programmes have been provided as complete entities so that repetitive entry of data is avoided. Nevertheless, the relevant values are printed as the programmes progress so that the reader can check the numerical results in stages.

The Appendices contain several programmes which may be useful, not only for the purpose of this book but also for other applications in general astronomy.

Cometary Theory in 15th Century Europe

Jane L Jervis, D. Reidel Publishing Company, Spuiboulevard, P O Box 989, 3300 AZ Dordrecht, The Netherlands. 1985, £27.95 (US $39.00), 209pp.

There must be few celestial objects which have excitied such reverence or fear over the ages, as comets. The story of these objects, from objects of Divine Wrath to dirty snowballs has a fascination hard to beat. This volume takes just one part of that story to provide examples of the different methological approaches of 15th century scholars to problems arising from observations of the sky.

It also focuses on Europe, for Chinese chronicles were not integrated into Western astronomy until much later, while Islamic astronomers were as blind to comets as European astronomers generally.

The book begins with references to cometary theory in antiquity and thus provides the background necessary to understand developments in the 15th century, for practically no new advances in cometary theory had taken place during the whole period up to that date.

The 15th century proper begins with Angelus, (the comet of 1402) who departs from Aristotle's treatment of comets as objects of a meteorological nature in favour of Seneca's, whose views had previously been dismissed but who saw them as celestial bodies which, owing to eccentric orbits, could only be seen in the lower part of that orbit.

The treatise of the comet of 1456 (later identified as Halley's comet) was written by Puerbach (1423-1461) and contains what seems to be the first attempt to determine the lower limit on the distance of the comet from the Earth. The results were useless but noteworthy that such an effort was made at all.

In the event, it was not until late in the 16th century that Tycho Brahe proved that comets were further than the Moon and thus made the old distinctions between celestial and terrestrial realms untenable.

TV Astronomer: Thirty Years of the Sky at Night

P. Moore, Harrap, 19-23 Ludgate Hill, London, EC4M 7PD. 1987, £12.95, 208pp.

A book about Patrick Moore, undoutedly the best-known astronomer in the UK today and couched in the author's inimitable style, is certain to prove of great interest.

It all began in April 1957 with what was intended to be a short TV series called "The Sky at Night" but which has continued to make it now the longest-running programme in TV history.

Over the past 30 years our view of the Universe has changed dramatically, with space exploration allowing men to set foot on the Moon, providing close-up views of Mercury, Venus, Mars, Saturn, Jupiter and Uranus, introducing the successful Giotto probe to Halley's Comet and adding new dimensions to our understanding through satellites such as IRAS.

All these have continued to reveal hitherto unsuspected celestial bodies and phenomena and paved the way to new theories of the origin and nature of the Universe.

The "Sky at Night" programmes have followed all these developments closely, almost in "blow by blow" fashion. Here, the author relates not only the progress of astronomy itself but also his experiences in the TV studio, fascinating and often highly amusing accounts in their own right.

The book is a milestone in the remarkable career of prolific author and populariser of every facet of astronomy and space.

Tethers in Space

Vol.62, Advances in the Astronautical Science, P M. Bainum, et al, Univert Inc., P O Box 28130, San Diego, California 92128, USA. 1987, 765 pp, hard cover $80; soft cover $70.

This volume contains papers presented at a conference, held in September 1986 at Arlington Virginia, on the application of tethers in space, one of the exciting new developments in space technology.

Session topics included are: (1) What can tethers do in space? - a tutorial, (2) Shuttle Flights: opening the era of tethers, (3) Tether dynamics: understanding behaviour and control, (4) Electrodynamics: new approaches to space power, (5) The space station era: tethers for science, technology and operations, (6) Technology development: the key to success.

Atmospheres and Ionospheres of the Outer Planets and their Satellites

S.K. Atreya, Springer-Velag GmbH, Postfach 10 51 60, Haberstrasse 7, D-690 Heidelburg 1, Germany. 1986, DM 148, 224pp.

This book presents a comprehensive treatment of the atmospheres and ionospheres of the outer planets and their satellites, a subject that has now attained sufficient maturity to warrent a monograph of its own. It also includes a theoretical discussion which emphasises the relevant physical and chemical processes and summarises significant observations to date, with details of the methods used for retrieving information from measurements. Shortcomings of theoretical models in providing correct interpretations of observational results are discussed with the object of stimulating new research.

As discussions of associated topics such as magnetospheres, interior and evolution are all limited only to those clearly essential to understanding the atmospheric and ionosphereic phenomena, a background is needed in physics, chemistry or mathematics - to undergraduate level - to get the dest out of the book. Some basic knowledge of meteorology would also prove useful.

The book is intended mainly for researchers and graduate students of planetary atmospheres, all of whom will find it most useful for reference.

Directory of UK Space Capabilities

The British National Space Centre. Obtainable from HMSO Publications Centre, P O Box 276, London, SW8 5DT. 1987, £9.95.

The BNSC has complied this useful directory of the space-related expertise available from more than 200 manufacturers, agencies and universities in the United Kingdom. It lists government departments, councils and research establishments, companies, trade associations, universities, polytechnics, institutes and learned societies, as well as individual companies and consultants. In each case details are provided of status, capabilities, and facilities available.

The book is divided into three main sections. Part I lists details of government departments, councils and similar establishments. Part II includes companies, consultants, trade associations and the like while Part III is devoted to universities, polytechnics, institutes and learned societies.

The BNSC provides a focus for Britain's space effort in science and technology. This, its first directory of UK space capabilities, provides a showcase of British companies and bodies experienced in a multitude of sectors related to space.

Communications Satellites

L. Blonstein, William Heinemann Ltd., 10 Upper Grosvenor Street, London, W1X 9PA. 1987, £9.95, 162pp.

This book is intended for those who know little about communications satellites but wish to know more. It begins with simple technical analogies and then proceeds, step by step, to a point where the reader can calculate for himself some of the essential technical characteristics of a space-linked communications system.

Every step is explained on the way, including the basic mathematical processes required, the reasoning behind the techniques used to determine selection and the ways of quantifying those parameters which determine the quality of voice, data or video. The volume also includes information on the economics of space communications both for satellite systems currently in use and those due to come into service shortly.

The Space Station

Hans Mark, Duke University Press, 1 Gower Street, London, WC1E 6HA. 1987, £23.70, 264pp.

President Reagan's approval of $8 billion for the construction of a permanent manned orbiting space station was the climax of one of the most important political and technological debates in the history of the US space programme. This account, by an author who played a major part in the development of the Space Shuttle from its beginnings in the 60's and who bore a primary responsibility for overseeing the space station project during the decisive years from 1981 to 1984, presents an absorbing inside account of science policy and politics during two US Presidencies. It not only captures the euphoria that characterised the space programme in the late 70's and early 80's but provides a unique perspective into the Challenger tragedy and the future of the US in space.

The author's appointment to the post of Deputy Administrator of NASA climaxed a distinguished career devoted to the development and management of space technology during which the Space Shuttle became a reality and the space station an acknowledged goal of the US space effort.

The author pays a superb tribute to the Society's founder, P. E. Cleator, and to his book "Rockets through Space" which appeared in 1936 and which he read at the age of 12, as well as to the Society itself, with the words:

"Slowly it dawned on me that Cleator and his colleagues were onto something really important and that I wanted, somehow, to be a part of it."

Longman Illustrated Dictionary of Astronomy & Astronautics

I. Ridpath, Longman Group UK Ltd., Longman House, Burnt Mill, Harlow, Essex, CM20 2JE. 1987, £4.50, 224pp.

This pocket-sized work defines terms, words and phrases connected with celestial objects and with space technology, grouped under main topic headings rather than alphabetically. It includes the basic astrophysics needed for an understanding of the universe and its evolution, galactic types and different star groups, as well as ground-based instruments used to observe these phenomena and the rockets, space probes and satellites which have contributed so much new information in recent years.

Additionally, there are a number of useful appendices eg on the planets and their moons, constellations, brief biographies of important space figures etc.

Challenger

Ed M. McConnell, Simon & Schuster Ltd., West Garden Place, Kendal Street, London, W2 2AQ. 1987, 269pp, £12.95.

The Challenger disaster on January 28, 1986 sent shock waves rippling throughtout NASA and the US administration. The author here presents a piece of "investigative journalism" which involved "sifting through thousands of pages of documents, following every lead and interviewing the essential participants" to provide an account of the events which led to the disaster.

His results are characterised by some of his chapter headings e.g. Part I is entitled "Years of Intrigue and Ambition" followed by chapter headings such as "Rehearsal for Disaster", "Certification of Deceit" and "A Decade of Compromise". The flyleaf goes further and claims that the book contains "the story you haven't read in the newspapers, the magazines or the Rogers Commission Report".

However, this is a most arresting book on a very distressing topic and, insofar as it contributes to the perception of the truth, it is to be commended. First-hand accounts based on interviews are particularly interesting and provide a valuable historical record. Even though much has, and probably will continue to be, written about the Shuttle disaster, the author, rightly, points the finger also at the pre-Shuttle era and to those responsible for its funding and who consistently pared down the project many times and thus, undoubtedly, contributed to the eventual turn of events. This is not to say, however, that they in any sense were guilty of "spending below the level of achievement"; as has so often happened elsewhere. The achievements of the Shuttle flights were great, even though, as is inevitable with such projects, an element of risk was always present. The question remaining was simply one of whether the element of risk was too great or should have been reduced or, indeed, did it stem from any man-made faults?

What is clear, is that however tragic the loss, it has provided a residue of good which can only expand and enhance future flights.

NASA Space Shuttle

H.R. Siepmann & D.J. Shayler, Ian Allen Ltd., Coombelands House, Coombelands Lane, Addlestone, Weybridge, Surrey, KT15 1HY. 1987, £4.95, 96pp.

This book provides a wide view of the type of activities preformed in the first phase of Shuttle operations to date viz over the first five years of operation. Since each flight had many characteristics which were unique, the book is written around an imaginary orbiter flight considered to have taken place at some time during the fifth year of operation, though many of the incidents mentioned really did occur during actual missions, with the words of the crew taken from NASA voice tapes made at the time.

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The Need for a Fifth Orbiter

Sir, Eugene Reichl discussed a rather important matter (***Spaceflight***, May 1987, p.253, "Only Four Orbiters"). Although his numbers seem to be a bit on the high side, it is clear that four orbiters will not be able to fulfill the manned space flight requirements of the 1990s. In contrast to his estimate I'd like to present one which is rather on the low side.

Prior to the 51L accident each Shuttle was scheduled to fly six missions per year in the late 1980s. If one looks at some turnaround intervals (e.g. between Discovery's flights 51D and 51G (59 days) or 51G and 51I (64 days), or between Atlantis' two missions (only 50 days)) he might think that this could easily be achieved. However, he forgets that the engineers had to work under immense pressure and that flight safety became less and less important. Despite John Young's warning that the nine flights in 1985 brought NASA to the edge of its possibilities, 11 missions with three orbiters had been planned for 1990 (October 1986 Shuttle launch manifest).

I think that when the four vehicle fleet has achieved full operational status early in the 1990s, the average turnaround interval at KSC will last some 75 to 90 days. So, in a best case scenario 16 missions per year might be achieved. This estimate, however, does not account for longer inspections, repairs or modifications that have to be made to every vehicle at some time.

Prior to the construction of the space station (i.e. until 1993) about 10 to 13 launches from KSC will be required; then there will have to be two launches per year from Vandenberg Air Force Base. So with one orbiter being used for alternate launches from Kennedy and Vandenberg a flight rate of about 12 to 15 missions per year might be maintained. When the build-up rate of the space station begins in 1994 the required annual flight rate at KSC will jump to at least 14 to 16. By that time the Vandenberg flight rate will increase, too, due to DoD requirements and Polar Platform servicing. This means that a fifth orbiter will be necessary!

Of course, it would be better to have even a sixth vehicle to reduce schedule pressures but a sixth Shuttle probably will not be approved by that time. Given the following preconditions, a five-vehicle fleet could fulfill the flight requirements throughout the nineties:

1. All commercial and some scientific spacecraft are launched by ELVs; the Shuttle will be used to launch only important scientific space probes that were specifically built for Shuttle launches (like Syncom).
2. The military flight rate does not increase; this primarily means that SDI will not be deployed.
3. Flights to service or repair satellites or the large space observatories will not be dedicated missions.
4. The space station servicing interval will be at least two months (no more than six missions per year).
5. The space station will not be extended until the late 1990s.
6. The Shuttle programme will not see another accident in which an orbiter is being damaged or even lost.

Construction of yet another vehicle in the late 90s due to increased space station activities could be delayed, as by then the European Hermes and the Japanese HOPE shuttle could be available.

Recently, Len Vernamonti was quoted as having said that a test vehicle of the Trans Atmospheric Vehicle could be available in 1993; this appears to be pretty soon. Assuming everything goes well, then the two vehicles might be operational shortly after the turn of the century. However, it is also possible that severe problems will be encountered during construction, so the vehicles would not be operational until 2010 or even 2015. A more exact date of the TAV's maiden flight can be given in a few years. I expect it to occur around 2005. This means that some kind of transition programme will be required. There are three possibilities of how such a programme might look:

1. Introduction of additional orbiters as postulated by Eugene Reichl.
2. Construction of two second-generation shuttles with less payload capability and a shorter turnaround time (about 10 flights per year, each) to be used primarily for space station servicing. These vehicles should be of new design so manned space flights are still possible when one of the two systems has been grounded, e.g. due to an accident.
3. Use of ELVs to launch consumables, spare parts or parts of spacecraft to be constructed on orbit. These supply modules would then be berthed and ferried to the station by an Orbital Manoeuvring Vehicle, and later be returned to Earth aboard a Shuttle. The main problems, however, are that the ELV to be used has to be made more reliable, and that the cargo must be able to withstand higher dynamic stresses.

Any of these possibilities is quite expensive, but there is no way to circumgo the higher flight rates of the next decade. Furthermore, the space station is expected to grow, so additional money will be needed for building new modules and for maintaining the space infrastructure. This means that NASA's budget will have to be raised. But for as long as even the construction of the core station has to be delayed, because the US Congress does not want to approve more money than originally estimated ($8 billion), this is very questionable.

A timetable that provides for the increasing flight rate could look like this:

1991: Fourth orbiter as Challenger replacement.
1994: Fifth orbiter to cope with space station missions.
1998: European and Japanese shuttles assist in space station servicing.
2000: Transition programme mentioned above: Either two new orbiters or two second-generation shuttles (delivery in 2000 and 2003).
2010: TAV becomes operational.

To meet that timetable it must be assumed that: the Shuttle will only be used for missions that require it; the military flight rate will not increase; no major accident will occur.

MICHAEL FICK
Selb, West Germany

Armstrong Moon Picture

Sir, With reference to the on-going discussion regarding the lack of photographs of Neil Armstrong on the lunar surface I must disagree with Mr. C.G. Legge (***Spaceflight***, June 1987, p.255) who states that the photograph shown in the January 1970 issue of ***Spaceflight*** looks "real".

This is a still from the cine camera set up to record the EVA from the LM's right hand window. It was set up to take only a few frames per second in order that the film lasted the entire EVA and hence when the film was shown everything was speeded up. The film was shown at the Apollo 11 press conference on August 12, 1969 which was published together with the photographs and stills in the form of a colour booklet in 1970 entitled 'The First Lunar Landing As Told by the Astronauts'.

K.A. McNEILL
Edinburgh, UK

Sir, Since mid-1986 I have been carrying out research on Apollo 11 lunar surface EVA photography; in particular I have been seeking a possible 70 mm frame taken with a Hasselblad camera showing Neil Armstrong during the EVA.

Armstrong has stated on a number of occasions that it is

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his belief that a 70 mm frame taken by LMP (lunar module pilot) Aldrin during the EVA shows himself in the background. However, many other persons who have in some ways been connected with Apollo 11 photography feel that Armstrong is mistaken and that no 'still' photograph exists showing Armstrong on the Moon's surface. It is known however that other photographs of Armstrong on the lunar surface exist. These were taken by a television camera and a 16 mm sequence camera located in the Lunar Module.

According to the Apollo 11 flight plan, which includes details of photographic tasks for the mission, LMP Aldrin was required to use the 70 mm Hasselblad camera once during the EVA. Aldrin's tasks were to photograph two panorama sequences, LM quadrants 1, 3 and 4 and LM +Z, +Y and -Z landing gear. The time allocated for these photographic tasks was ten minutes. At the end of his series of photographic tasks the LMP was required to hand the camera to Armstrong. At no time, according to the flight plan, was the LMP required to photograph Armstrong, although Armstrong was required to photography the LMP on a number of occasions.

Following a detailed analysis of Apollo 11 70 mm Hasselblad EVA photography and correspondence with Neil Armstrong, one 70 mm frame has been identified which might possibly show the Apollo 11 commander in the background. The frame number of this particular view is AS11-40-5886. It shows the US flag, the Solar Wind Collector experiment, an astronaut and a partial view of the LM. The astronaut is standing close to the LM (in shadow) working at the Modularized Equipment Stowage Assembly (MESA).

AS11-40-5886 was taken at the time LMP Aldrin was due to use the Hasselblad and it could well represent one of Aldrin's first photographs with the Hasselblad camera. Armstrong at this time during the EVA should have been completing the bulk sample collection activity. His tasks would have included sample weighing, packing and sealing the sample return container and connecting the sample return container to the lunar equipment conveyor for later transfer to the LM. These activities would have taken place at the MESA – and this is exactly where the astronaut in AS11-40-5886 is shown working.

Neil Armstrong confirms that AS11-40-5886 does show himself on the lunar surface. Edwin Aldrin has also confirmed that Armstrong was photographed on the lunar surface. However, it is unlikely that AS11-40-5886 or any other Apollo 11 70 mm Hasselblad EVA photograph will ever be *positively* identified as showing Neil Armstrong. It is clear that no 'good quality' EVA view of Armstrong exists. The best EVA views of Armstrong are those obtained with the 16 mm sequence camera which show his first steps on the lunar surface, contingency sample acquisition and other activities in the close vicinity of the LM. This same camera later automatically photographed both astronauts.

If AS11-40-5886 does indeed show Armstrong then it is a very rare photograph indeed, for it represents the only 'still' photograph of Neil Armstrong conducting the first lunar surface EVA.

KEITH T. WILSON
Strathclyde

Surviving Re-entry: A Reply

Sir, This is in response to Neil Roger's question of what would happen to a piece of paper or foil dropped from low Earth orbit (***Spaceflight***, March 1987, p.93).

The paper or foil would have the same amount of kinetic energy relative to its size as any spacecraft, so, unless the paper or foil were thermally protected, it would burn up during reentry.

RANDY BOND
Utah, USA

Joseph Kerwin's NASA Service

Sir, In the June 1987 issue of ***Spaceflight***, p.234. it is stated that Dr. Joseph Kerwin has been a NASA astronaut since 1965, implying that he has been an astronaut for the last 22 years. However, he resigned as an astronaut in May 1982 but did not leave NASA. From 1982 to 1984 he worked as NASA Senior Scientific Adviser in Australia and though there were signs that he might return to flight status in 1984 he did not; instead, he served as Director of Space and Life Sciences at the Johnson Space Center. It is strange, though, that in the yearly NASA publication "Astronauts Fact Sheet" he was still mentioned as an active mission specialist.

A year ago, I wrote him a letter in which I asked whether he was still an astronaut with flight status and found this not to be the case.

TON VAN ROOIJ
Eindhoven, The Netherlands

Mir with Four Modules

Sir, Having read the article on 'Mir in Action' and seen the beautiful drawing by Peter Smolders (***Spaceflight***, April 1987, p. 134), one might attempt to identify ways that the Soviet space station will be operated during the next few years.

The long-term crews required for doing the science made possible when all the scientific modules have been added should amount to some 6 cosmonauts (including some four research cosmonauts from different scientific fields). This will require two Soyuz TM spacecraft docked at the complex regardless of the Progress ferries. One of the Soyuz TM's could dock at a certain radial module.

If we assume a 21 ton weight for each of the radially located modules we end up with the following all-up weight: 4 x 21 + 21 (Mir) + (Kvant) + 2 x 7 (Soyuz + Progress) = 131 tons (for one Soyuz) or 138 tons (for two Soyuzes). This is more than the estimated total weight of the complex. It is possible that all the modules could have a jettisonable service pod leaving 12 ton modules with docking adapters at the outer ends. The all-up weight would then be 95 tons (for one Soyuz) or 102 tons (for two Soyuzes) with a Progress ferry.

Adding another solar panel on the Mir core station increases the total useful collecting area to 114 m^2. If another two modules are to have similar solar panels then the total area for the complex would be 114 + 2 x 76 = 266 m^2, excluding the solar cells around the modules, thereby providing up to 25 kw of power for the complex.

Orbital correction for the complex will require a considerable amount of fuel. One way to do it would be to have a heavy Cosmos module dock to the Kvant to boost the complex to a 400 km circular orbit preventing fast orbital decay. The Soyuz TM series should have the capability of manoeuvering in higher orbits when all the fuel-saving measures are taken into account together with the weight savings.

Finally, these modules could be serviced using the Shuttle that is being developed. The astrophysics module could be brought back to Earth after the initial program is accomplished for servicing and instrument modification, sometime in 1989. The spaceplane that is also expected to be operational by 1990 could transport several scientists for short-term visits to the Mir complex.

With the launch of the SL-W Energia booster on May 15 and TV coverage of the event, it looks like the Soviet space programme will give up its secrets in the foreseeable future and that live coverage of a Soviet Shuttle launch can be expected next year.

M. Q. HASSAN
Bagdad, Iraq

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All Woman Crew

Sir, Forgive me for writing in Russian. I am sure that it will be easier to have my letter translated than to decipher my English. I have been reading *Spaceflight* for some years and find much that interests me in it. So it is very disappointing to discover an inaccuracy.

The article "All Woman Crew" in *Spaceflight*, January 1987, p. 17 states that Valentina Tereshkova achieved space flight aboard Vostok-6 in February 1962. In fact the Vostok-6 flight took place in June 1963. In February 1962, V.V. Tereshkova was still in training for space flight.

Spaceflight has much interesting material in it. I was delighted for example with the publication of the photograph of the group of Canadian astronauts in training. I think all readers would be interested if similar material about Italian, Indonesian and Japanese astronauts in training could be published. Information on the formation of other groups of categories of personnel connected with space flight and photographs of them would also be useful.

VADIM E. MOLCHENOV
Tula, USSR.

Ed. *Our thanks to Mr Molchenov for putting the record straight on the date of the Vostok-6 flight. We are always pleased to publish photographs of groups of astronauts and of people connected with space flight as they become available.*

The Lesson of the Paperclip Conspiracy

Sir, The documentary film 'The Paperclip Conspiracy' (*Spaceflight*, June 1987, p. 257) throws new light on America's Apollo space triumphs in the late 1960's and early 1970's. It shows that the United States, in its frenzied drive to maintain superiority over the Soviets in intercontinental ballistic missiles and later space technology, brought out of Germany at the war's end over 1,000 of the worlds best rocket scientists, many of whom they knew to be Nazis, SS officers, and some guilty of the most horrific war crimes. The documentary showed that over 20,000 innocent people were put to death through enforced starvation, torture and summary executions at the Nazi's rocket factory at Nordhausen. The film showed that the rocket team were responsible for the conditions in the camp.

The Soviets also took some V2 scientists, though far fewer and of poorer quality. However, there is one major difference, the Soviets did not make them national heroes and they were ruthless in their punishment of war criminals at the war's end.

It is also interesting that many leading space and aviation historians, who dig behind the scenes in the Soviet space programme, have not exposed the Nazis who were in the US space programme.

For one very simple reason, the politics behind both space programmes stink, and that is the involvement of the military and the military potential of space. It seems to me that the only way to stop the recriminations on both sides and the only truly scientific and progressive way forward for both space programmes is to abandon Star Wars and for the United States and the Soviet Union to take up a joint manned mission to Mars.

We must ensure that the next generation of scientists do not get roped into space programmes that become increasingly militarised as who knows what crimes these scientists may commit in the naive pursuit of their science in the event of some future war.

A. M. HOLT
Liverpool, UK

The Historical Significance of Apollo

Sir, In the course of arguing for the usefulness and necessity of space exploration, Edward Lyons recently felt justified in describing the Apollo programme as "a one-off, short-term, prestige-gathering exercise" and "a dead end" [1], while another contributor to your columns has written: "Apollo, while brilliant, is recognised in an historical view as an expensive path leading nowhere" [2]. Surely it is a scandal that comments such as these can be made and pass unchallenged in the pages of Britian's leading astronautics magazine!

In 1969, it seems, people had a clearer vision of the significance of Apollo. I have before me as I write an article by Dr Rodney Johnson, who was Advanced Planner at NASA's Advanced Manned Missions Program Office in Washington DC at that time. Entitled "The Lunar Colony", Johnson's article offers a tantalising glimpse of the direction in which Apollo was then perceived to be leading the space programme. A two-page diagram in his article shows an artist's impression of a broad tract of the lunar surface with a number of modules and buildings dispersed over it in distance to represent their dispersal in time. One is labelled "Apollo Lunar Module (1969)". The next is: "growth module (1970)". Then come "expanded base (1971-73)", "way station and emergency shelter (1974)", and finally: "scientific station (1975) developed into lunar colony (1978)". The caption, which summarises a more detailed argument in the main text of Johnson's article, reads in part: "Bases on the Moon would begin with the Lunar Module used in today's Apollo system ... By the mid to late 1970's a scientific station should have been established, and this will probably grow into the first large lunar colony. A modular 24 man colony is suggested above ... To establish such a colony would require 10-12 Advanced Saturn V flights" [3].

How then, has it come about that these sanguine expectations of Apollo's potential for future development have, 18 years later, been replaced by the dismissive evaluation "a dead end" and "leading nowhere"? I believe it is because even now some people feel the need to justify in rational terms the decisions taken in the United States around the year 1970 which killed off Apollo and gave birth to the development of the Space Shuttle. Perhaps, given the economic and social climate of that time, these decisions were inevitable. But surely it is not necessary to pretend that they were a just verdict on the tremendous capabilities that the Apollo-Saturn system had given the United States?

In his courageous and authoritative letter last year, James French reminded us that the magnificent Saturn was itself "potentially capable of a substantial upgrade" and "could have evolved toward partial reusability" [4]. Clearly, Apollo-Saturn was in itself anything but a dead end. And indeed the verdict of the 1970's did not apply to that programme alone but to a number of promising space projects - notably the up-and-coming research into both solid-core and gas-core nuclear propulsion, which at that time seemed poised to send United States astronauts ranging far and wide through the Solar System. The dead end, if there was one, was therefore not specific to Apollo at all. It was a political or social dead end, or rather failure of vision, not a technological one. It was not even an economic dead end, as the champions of reusable launch vehicles might wish to assert, for the billons of dollars invested in Apollo were always tiny compared with the sums spent, then as now, on social welfare and on the arms race. (Let us hope that, when their turn comes, the Soviet leaders will show more steadfastness of purpose!).

I should therefore like to propose a more generous view of the historical significance of Apollo. I believe that Apollo-Saturn was no dead end, but was rather a gateway to the universe of such awesome proportions that the American people collectively balked at crossing the threshold. This applies to the specific hardware employed as much as to the mission. It applies particularly to the vision: a "focus upon doing missions", as James French describes it in his letter, as

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opposed to an effort "towards new development", for this single-minded focus on the mission objective of a Moon landing was, I believe, among the factors responsible for Apollo's amazing success.

Edward Lyons in his letter states that Apollo is "not a good example to cite when debating the pros and cons of space flight". Surely this statement is the very height of absurdity! Apollo-Saturn is the only space project to date which has physically landed men on the shores of a new world: it is therefore arguably the only example to cite! - and, at the least, certainly the pre-eminent one.

* * *

For, after all, what is it really all about? What is to be the philosophy of space-age man? Is he doing missions in order to fulfil a domestic political or social purpose or develop some new technology? Is he only supposed to embark on missions which are a "logical step" forward? Or is he to be allowed a visionary philosophy? - one in which the missions are imbued with a sense of mission, however, "illogical" or lacking in practical applications they may seem. In the visionary sense, Apollo and the constellation of lunar, planetary and technology programmes that preceded and complemented it are the very quintessence of space exploration. Communications satellites and space-based manufacturing, when they are oriented towards terrestrial purposes, are not, precisely because their purpose is terrestrial. The visionary philosophy is that which proclaims extra-terrestrial goals; such a goal was, of course, the first flight to the Moon.

Yet why should the mission come first in this way? Where is its justification, if not to serve human ends? In answering this question, we find a clear echo of the underlying philosophical foundations in a letter printed adjacent to Edward Lyons's in the very same issue of ***Spaceflight***.

In this letter, Peter Mills gives an account of the contents of a book entitled The Solar System, by Thomas Dick LLD and published in 1846 by The Religious Tract Society of London. What I find remarkable about this book is the belief that all the bodies of the Solar System, from mighty Jupiter down to and including even the comets, must surely be the abodes not just of life, but of self-conscious, intellectually developed forms of life capable of understanding their environment and, no doubt, of glorifing their Creator. The quotations which Peter Mills includes in his account convey to me a terrific sense of the waste of a unique opportunity that would inevitably occur if even one of these worlds were left barren. Given the author's and publisher's belief in a benevolent and efficient Creator-god, a barren world was therefore deemed to be highly improbable.

But in fact the opposite appears to be the case: everywhere we of the space age look, the worlds turn out to be barren. So were Thomas Dick and the Religious Tract Society of London merely displaying a quaint, naive nineteenth-century prejudice, or could there be more to it than that?

It seems to me that human beings are capable of experiencing a distinct sense of waste or of irrecoverable loss with a particular feeling of poignancy. In particular, a barren planet can be seen as a wasted opportunity. For example, science-fiction writers have populated Mars with a great number of hypothetical civilisations, yet once our space probes began to reach the planet we found that nothing resembling those empires had ever existed. Mars is therefore a place where consciousness could conceivably have arisen but in fact did not. To sum the case up: there have been (say) a billion sunrises and sunsets on Mars, yet none of these was ever witnessed by a conscious intelligence: our response to this, speaking ourselves as conscious intelligences, has to be: "What a waste"!

In general, space-age man does not seriously believe in a benevolent Creator-god. Yet let us suppose that, despite his lack of religion, he shares with Thomas Dick the sense that it is fitting that all worlds should be arenas for the development of consciousness, intellect and culture. Then let him see with our modern eyes the lifeless, rubble-strewn plains of Venus, the Moon and Mars: will he not experience a poignant sense of waste? - a sense of outrage, if you will, at the thought that so vast a proportion of the universe has been left for innumerable ages barren, lonely, unknowing and unknown, while so minute a proportion has been set aside for the enjoyment of sensitive and intellectual beings. Then well might he say, with Pascal, "The eternal silence of these infinite spaces fills me with dread" [5]. But he would also want to do something about it, for he would experience the desire, in common with all living beings, to extend his territory and multiply his kind: in short, the desire to end the intolerable loneliness of these deserted worlds by colonising them.

* * *

Of course, one cannot state meaningfully what the purpose of the Apollo project was, beyond the bare fact of landing on the Moon, because to different observers at different times the programme meant such different things. At the outset, to most people, the ultimate purpose was simply to beat the Russians and restore United States prestige; later on the scientific angle came to the fore, and Apollo became a means of studying lunar geology. To some, it was a great adventure undertaken for its own sake; to others, it was an irrational, extravagant gesture from a corrupt economic system; to yet others, no doubt, its ultimate purpose was to reinforce and expand the R & D empire that was technocracy in the United States.

Yet if one day soon men return to the Moon, this time to stay, these short-term, contingent goals will tend to pale into insignificance beside the abiding fact that Apollo was first to prove that flight to the Moon is possible and that, once there, one can live on the Moon. If mankind is to spread beyond his planetary cradle then the significance of Apollo - even long after it has been forgotten - will be that it was the first step onto the extraterrestrial foothold, no matter how brief and precarious a foothold. It was, in other words, a crucial step in the proliferation of conscious, rational thought from one world to many. Therefore, it was also a step in the direction of realising a certain vision of the universe: mankind starting on the task of populating the worlds which the Creator ought to have peopled with intellectual and cultured beings, but which He unaccountably failed to do. And this existential imperative, implicit in the activities of living beings and societies, seems to me to be fundamental to life itself.

We live: therefore as individuals we must either grow or decline; there is no standing still. This law applies also to the species as a whole: either to grow, or to decine. To grow means to expand - geographically, technologically, and culturally. In our present historical context, this means inevitaby to follow Tsiolkovsky's dictum and spread our kind beyond its planetary cradle. Man cannot live in the cradle forever - and if he refuses to grow out of it, he must therefore decline and fall, eventually to die out. The significance of any space programme when seen in this, the longest perspective of which humans are capable, must therefore be: how much it contributes to this process - how much human seed it has sown, and how far afield.

Apollo-Saturn remains the towering pinnacle of space exploration to date. An "expensive path leading nowhere"? A "dead end"? No; we should rather remember it as a bargain-price path leading to new worlds, and ultimately to the stars.

STEPHEN ASHWORTH
Oxford, UK

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2. P. W. Mills, in ***Spaceflight***, vol, 28 (Sept/Oct. 1986), p. 351.
3. R. W. Johnson, "The Lunar Colony", **Science Journal**, vol. 5 (May 1969, special issue: "Man on the Moon"), pp. 82-8.
4. J. R. French, in ***Spaceflight***, vol, 28 (April 1986), p. 183.
5. Pascal, Pensées, no. 201 (Penguin Classics edition), or Brunschvicg no. 206.

CORRESPONDENCE

Spaceflight

Sir, ***Spaceflight*** is visually very pleasing now, and I would not want to miss a single issue. The June issue, in complementary oranges and blues, is particularly striking. The spaceplane looks like it should race right up off the page!

I was pleased to see on p. 227 of the June issue that Mr Tony Lawton had also surmised that the first flight of the Soviet shuttle would be "automatic". In a letter I had published in the September/October 1986 issue I surmised the same thing, at least for the ascent phase of the first shuttle flight.

Keep up the excellent work.

DAVID S. F. PORTREE
Illinois, USA.

Man in Space

Sir, I found the article on 'Man's Role in Space' (***Spaceflight***, June 1987, pp.240-247) of some interest. However, a couple of errors crept into the captions to the (spectacular) pictures.

The astronaut with an MMU stinger about to dock with Westar VI (p.241) is Dale Gardner, not George Nelson as indicated. Nelson flew on STS 41-C and flew an MMU to dock with Solar Max.

The view of an orbiting Shuttle (pp. 242-3) bears some resemblance to that from Bruce McCandless's EVA in an MMU, but on closer examination it proves to be a photo taken from SPAS-01 on STS-7. (Note the RMS cocked in a 7-position). On STS 41-B, during which McCandless performed his EVA, the structure supporting boxes and Getaway Special canisters is further forward than on the picture in the article.

Despite our limitations, the human presence is and will continue to be vital in many space operations. The unparalleled capacity of humans to recover successfully from a crisis has been demonstrated many times by US astronauts and (more recently) by cosmonauts Romanenko and Laveikin. Long may it continue to be so.

RALPH D. LORENZ
Henley-in-Arden, UK

Ed. *The same corrections have been received with our thanks from Michael Crowe who adds:*

The series of pictures taken by SPAS have often been used to illustrate a lot of media stories on the Shuttle. I always wince when the media, both in print and on TV, use the pictures as being from the 'latest' Shuttle mission when the RMS arm parked in the '7' position clearly identifies it as being from the seventh Shuttle mission, which was in June 1983. So far, thank goodness, ***Spaceflight***, has yet to make that mistake.

MICHAEL A. CROWE
Waramanga, Australia

Deane Davis — *An Appreciation*

We regret to record the death at the age of 81, of Deane Davis, a Fellow of the Society and formerly of La Jolla, California until his retirement to Hawa, Hawaii. In spite of threats, blandishments and seductive talk, Deane was never persuaded to prepare a Personal Profile about his distinguished career for publication in ***Spaceflight***, though insights into his fascinating life appeared in his account of the Atlas rocket development, "Seeing is Believing" (***Spaceflight***, May 1983), and more fully in "The Coming of Age of US Rocketry" (*JBIS*, April 1986), which described some of his personal experiences during the 10 years of US rocketry developments leading to the launch of Atlas 3B on July 19, 1958.

His letter describing a meeting with President Eisenhower the day after the successful SCORE (space communications) launch in December 1958 is in typical style:

I woke to find someone trying to knock my door down. It was Hank Eichel feeling no pain and absolutely splendid in a full dress uniform. I'd never seen him that way. "Put on your best scarf and rompers, old chap," he said in a phoney English accent, "the air-crahft awaits to dither us thither to the white-washed halls, y'know. Ike waiteth, the cah waiteth, the air-crahft driver waiteth and I could use a spot." And he poured the last of my Tanquerey. He sounded like a Heine trying to imitate Pongo Twistleton – which was exactly the case.

Deane Davis

He continued:

When we finally got back again to food, I ended up in a foursome of the President, Mr. Johnson and General Towers grouped around a small coffee table. I was directly across from Ike shovelling it in as fast as I could under the circumstances. "What is your handicap?" Ike asked me. "Well, sir, it isn't talking too much," I said.

Deane, an aerospace engineer of many years standing at General Dynamics, Convair Aerospace Division, was intimately concerned with the development of the Atlas rocket, and its variants, from the earliest days. His circle of friends included many who contributed to the American Space Programme. Deane, unlike one of his closest friends, Kraft Ehricke, a Fellow of the Society and a visionary before his time who also died recently, was a down-to-earth engineer and always one of the first to get to the nub of any problem. This, combined with his wit, charm, great discernment, an impish sense of humour and ever-ready smile, made him an irresistible companion. (See his account of his trousers catching fire while giving a presentation before a distinguished audience following the successful Surveyor flight, reported in "From the Secretary's Desk", ***Spaceflight***, February 1985, p.94). Many members of the Society will recall this for themselves when Deane held them enthralled in an impromptu talk at an HQ meeting during one of his all-too-rare visits to the UK.

His humour and his great love of the United Kingdom prompted an essay "A Child's Garden of English History" which steadfastly remained as a strictly type-written draft. Had he finished it, it would surely have been a best seller. Deane also developed his own style of painting, which he coded "perspecs" (a two-dimensional exercise in perspectives) many examples of which were space-inspired.

Deane had promised to return to the UK again. Now we wait in vain.

Len Carter

To The Moon On The Cheap

The obvious advantage to building a spacecraft of low mass is that it greatly simplifies the task of moving the spacecraft from Earth to its destination. This benefit is particularly significant during the present period of reduced launch capability, but in any case it makes the associated mission easier to fund and schedule. A study team at JPL has recently developed a low-mass spacecraft and propulsion concept that would allow a systematic programme of low-cost lunar science. In addition, demonstration of the propulsion system, a solar-electric ion engine, in this mission environment could reduce development costs for this technology for subsequent applications to more exacting interplanetary missions. Their findings were summarised in a report at the AIAA Electric Propulsion Conference at Colorado Springs in May.

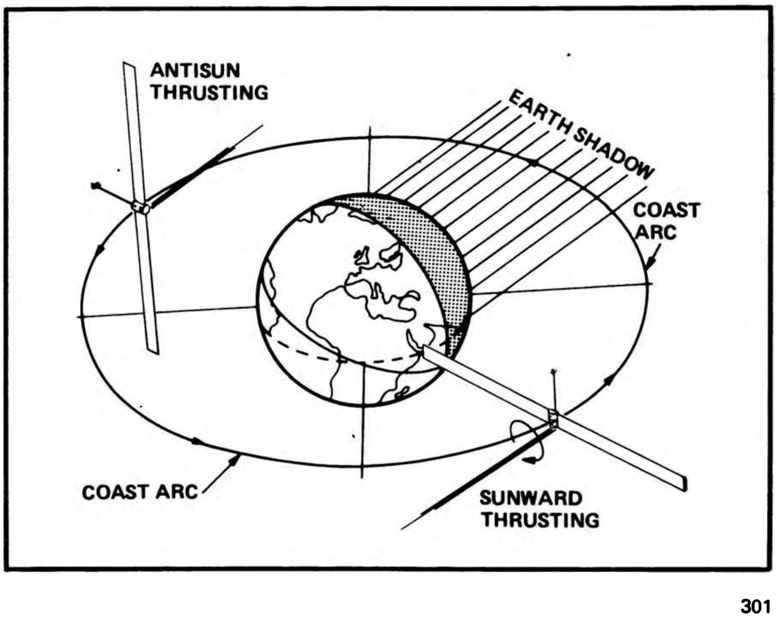
Since the Challenger accident and, in particular, the cancellation of the Centaur rocket as a high-energy upper stage for Shuttle, the situation has been exacerbated. Gravity assists from the inner planets will be required by Galileo in order to get it to Jupiter, but the process will consume six years rather than the two-year direct flight time that was originally planned with the Shuttle/Centaur combination. Similar remarks apply to the proposed NASA/ESA Cassini mission to Saturn. Ion propulsion techniques (solar-electric or nuclear-electric), if they were available, could be used to some advantage. However, the technology is not proven, and the first-time cost of development for a flight project could be high.

Kerry Nock of JPL is leading the LGAS study team; the acronym "LGAS" stands for "Lunar Get-Away-Special" in recognition of the study team's plan to stow the spacecraft in a canister aboard the Shuttle for initial deployment into Earth orbit as part of NASA's Get-Away-Special programme. Nock should be familiar to Society members as the editor of the August 1984 ***JBIS*** special issue on Solar System Exploration and as the source of several innovative mission concepts which have appeared in these pages. Although the Shuttle would provide a very convenient mode of access to Earth orbit, there are approximately 25 other launch vehicles in the world, including NASA's Scout, that could support a launch of this low-mass spacecraft, either in a dedicated or piggyback mode. Now that is versatility!

Deployment from the Shuttle would follow opening of the GAS canister and spring ejection of the spacecraft at 1 m/s. The first task of the new Earth satellite, after unfolding its solar array and science boom, would be to begin a search for the Sun, using two small cold xenon gas thrusters to manoeuvre its attitude. The spacecraft's attitude would be controlled by spinning it at a few rpm, and the main-engine thrusters are to be aligned parallel to the axis of spin. With the Shuttle at sufficient distance, the thrusting program would begin.

At the start of the mission, the ion propulsion system would consume 1400 watts from the solar-array output, about 70 per cent of the spacecraft's available electrical power. To add energy to the orbit and initiate a slow spiral out from Earth, xenon ions would be expelled from the two main thrusters during the two 90 degree arcs of the orbit when the thrusters are pointed nearly along the velocity vector of the spacecraft. During the other two 90 degree arcs, the spacecraft would coast. The propellant load constitutes about 36 kg of the total spacecraft mass of 150 kg.

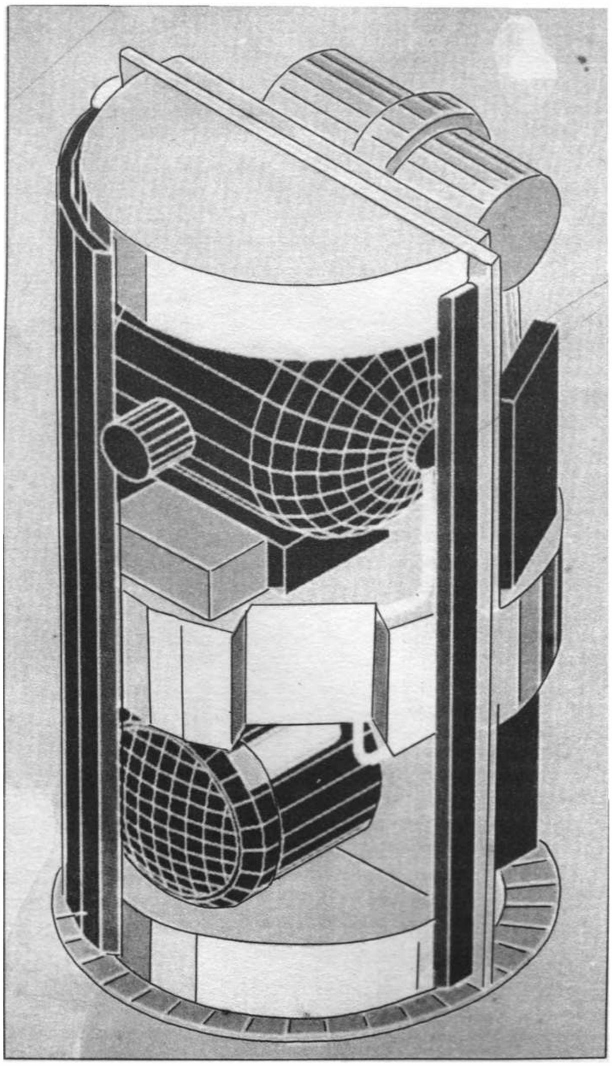
In the course of their study, the LGAS team found that their Earth spiral strategy, although independently devised, had been first proposed in 1972 by H.W. Scheel. Scheel envisaged a low-thrust system which would be used to raise a TV-satellite from low-Earth to geosynchronous orbit.



A low-mass, ion-drive spacecraft could slowly creep out of Earth orbit and arrive, in about two years time, at the Moon. In this cost-effective manner it would be possible to carry out an incremental programme of lunar science with modest launch-vehicle requirements. *JPL*

Kerry Nock, LGAS study team leader, with the stowage (on the Shuttle) envelope for the spacecraft with which he hopes to conduct low-cost exploration of the Moon. Nock used this direct approach to challenge his team "to think small". *NASA/JPL*

View of LGAS spacecraft (from Sun-side and with one solar panel removed) as it would be stowed in a Shuttle Get-Away-Special canister. *NASA/JPL*



The technique of low-thrust propulsion owes its effectiveness to a tortoise-like persistence. The increase in altitude at the beginning of the Earth spiral phase is calculated to be about 20 km per day, and the total thrust would only exceed the force due to atmospheric drag by about a factor of three.

Gaining altitude and escaping from the sticky fingers of the atmosphere, the spacecraft would face a new challenge as it entered into the more intense portion of the Earth's trapped-radiation belts after about 75 days of thrusting. Radiation always poses hazards to electronic systems (which would be radiation hardened for LGAS) and degrades the efficiency of solar arrays. The outward spiral from Earth is planned to last about 650 to 700 days. Variations in duration are dependent upon launch conditions, which would determine the thrust/coast strategy most suitable for positioning the spacecraft for capture into a polar orbit around the Moon.

Inward spiraling to the Moon would be accomplished by removing energy from the orbit with the ion propulsion system over a time span of about 150 days. The final circular orbit is planned to be at a favourable observing altitude approximately 100 km above the lunar surface.

The scientific payload for the first mission would consist of a 10 kg gamma ray spectrometer. With this instrument it may be possible to discover frozen water in (shadowed) lunar polar regions, if that substance exists in concentrations as high as one per cent to three per cent in the top one metre of soil. Water would be very important to future utilisation of the Moon. A polar orbiter such as LGAS would also be able to extend and refine the Apollo (near-equatorial orbits) survey of the elemental composition of the lunar surface, extending fractional coverage from the present 23 per cent to all of the surface of the Moon. A third scientific objective is the detection and precise location of direction of astronomical gamma-ray burster sources in conjunction with other spacecraft including, possibly, the Mars Observer, Ulysses, and Soviet Mars missions. Astronomers believe that gamma-ray bursts may originate in neutron stars.

Doppler tracking (S-band) of LGAS would double the existing gravity coverage of the Moon. This type of information yields insight into internal structure and would be of aid in navigating future lunar missions.

The return of data is planned at a rate of 1024 bits per second with a transmitter power of one watt. Half of the data stream would be devoted to realtime science and engineering and half to data played back from the 1.5 megabits of on-board random-access memory, which allows recovery of lunar farside data.

The programme of incremental lunar science that would be possible through a series of missions like LGAS, and the technological benefits derived from these expeditions, do not represent the limits of the concept. Indeed, "small is bountiful" because Nock says his study team has concluded that the spacecraft may also be suitable for missions to some near-Earth asteroids, if a Delta launch vehicle were used. The scientific and potential economic value of extending the survey capability of LGAS to these small bodies could be enormous.

The current team effort is supported through study funds. Nock hopes to interest the science community and NASA in the LGAS concept to the extent that it becomes an approved project. If this were to occur, the earliest feasible launch date would be July, 1991.

Space at JPL

Scanning Tunnelling Microscope

The search for distant objects and the description of their properties constitute an important aspect of astronomy. Galileo's application of the newly discovered telescope provided a major capability for the implementation of this program. The great Italian astronomer and physicist realised that lenses could also be combined in a manner to yield views of nearby objects: enter the possibility of the microscope. Kepler, whose name is usually associated with astronomical topics, also made contributions to the theory of the microscope. The seventeenth century saw exciting developments in applied microscopy with the observations of scientists such as Malpighi, who was able to observe small capillaries connecting the arterial to the venous circulatory systems, and Leeuwenhoek, who observed single-celled animals.

The resolution of optical microscopes is limited to about one third of the wavelength of visible light. Thus, one cannot expect to resolve objects smaller than approximately 1500 Å. One angstrom (Å) equals 10^{-10} meters and is often employed in describing the dimensions of atomic-sized systems, which will figure in the subsequent discussion.

The techniques of modern physics have come to the aid of the microscopist, and electrons, with their short wavelengths, have been substituted for photons to illuminate the object to be viewed (in 1925 de Brogile introduced the idea of matter waves associated with particles). The transmission electron microscope is quite analogous to its optical counterpart but employs magnetic "lenses" to focus the electrons. The (thin) specimen is illuminated by a beam of electrons focused by a condensing magnetic lens. After traversing the specimen, the electrons enter a converging magnetic lens, analogous to an (optical) objective lens, and the resulting image is magnified by another magnetic lens. The image can be conveyed into the optical domain by a fluorescent screen or a photographic plate.

Typical resolving powers achieved by this instrument fall in the range of 25 to 100 Å, clearly an improvement over optical techniques but not down to the atomic realm of 1 Å or thereabout.

The first instrument capable of resolution at atomic levels was the field ion microscope, whose roots go back 50 years. A more versatile instrument, capable of producing images at atomic-level resolution over a surface area, has been developed in the last 10 years. Heinrich Rohrer and Gerd Binnig of IBM, Zurich, received the 1986 Nobel Prize in physics for the invention and development of the scanning tunnelling microscope (STM). Not only can resolutions under 1 Å be obtained, but spectroscopy is also possible. That is, both the topography and the composition of a surface can be investigated at the atomic level.

The center for Space Microelectronics Technology, recently established at JPL (see the May 1987 edition of the column), is one of a number of locations worldwide where research on the STM is being carried out. The field has proved so fertile that in July the Second International Conference on Scanning Tunnelling Microscopy/Spectroscopy, was held in Oxnard, California.

William Kaiser leads the STM semiconductor investigation group at JPL, within the Center for Space Microelectronics Technology. It is planned to use the STM in the process of producing high quality devices for applications in submillimeter astronomy, communications and computing. The STM supplies a "report card" on how well critical materials have been fabricated.

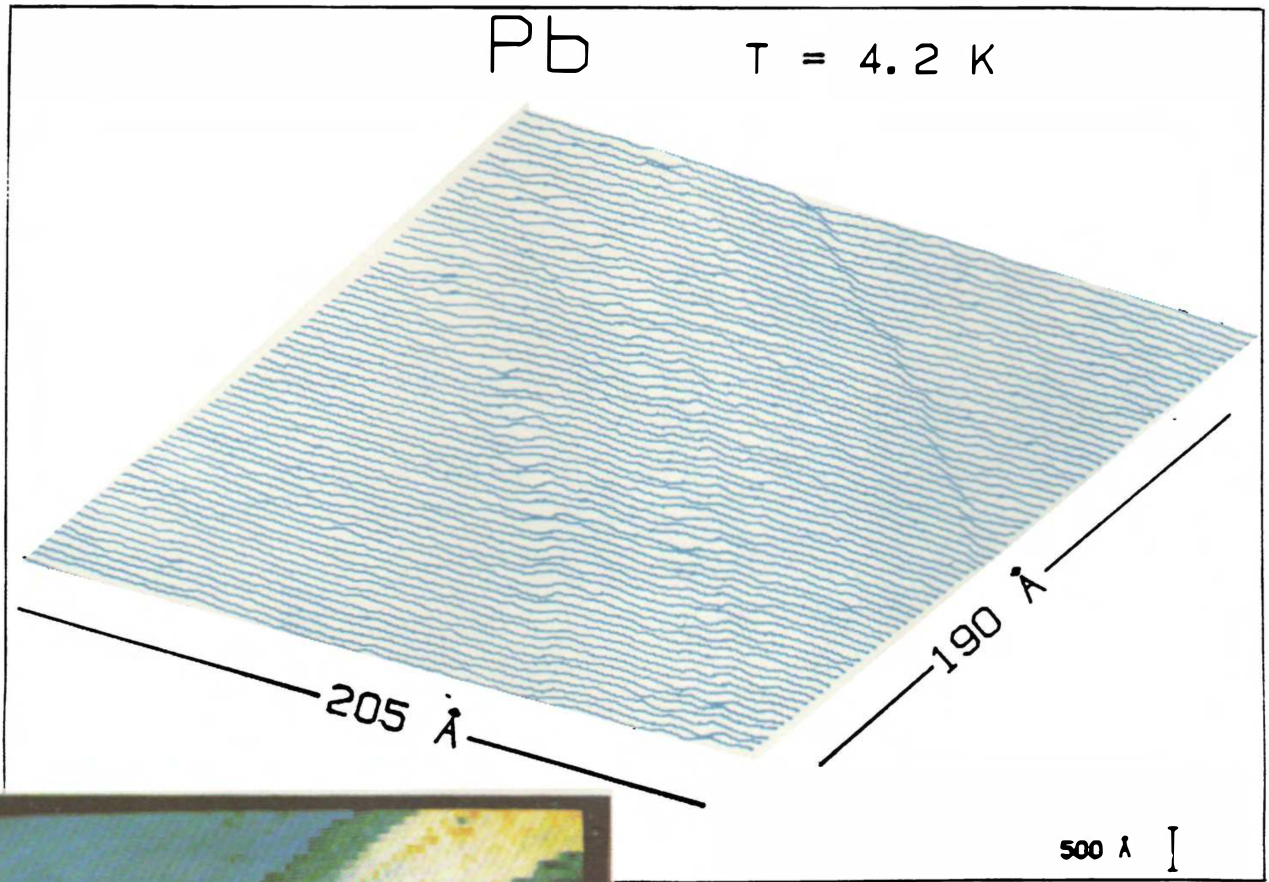
Building upon the work of de Broglie and Bohr, the Austrian physicist Erwin Schrödinger developed the subject of wave mechanics within quantum theory and shared the 1933 Nobel Prize in physics with Dirac. Schrödinger associated a wave with each particle and developed his famous wave equation that mathematically describes the state of the system in space and time.

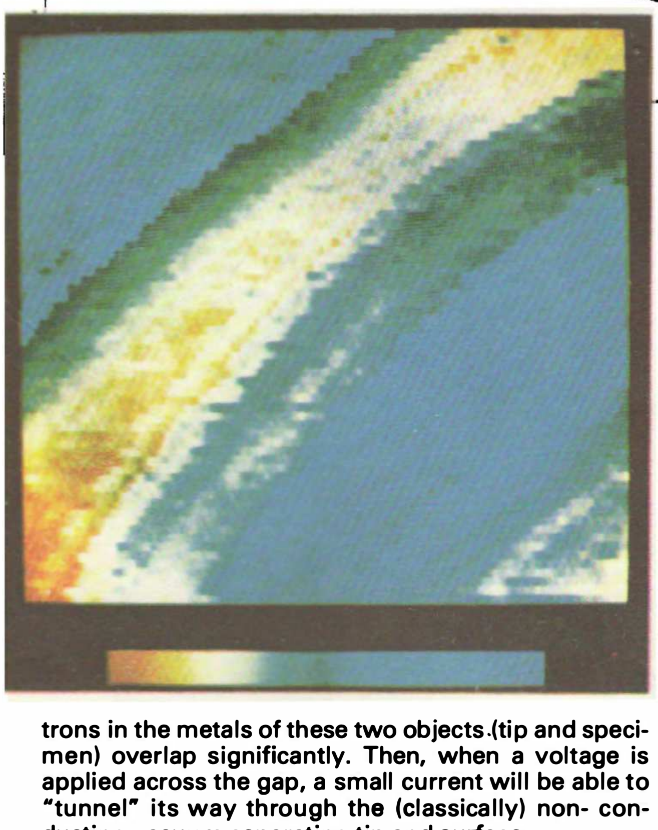
The most important physical interpretation of the wave function comes from its use in describing the probability of finding the system in a specified state. For example, given the wave function for an electron (obtained by solving Schrödinger's wave equation using applicable modeling and boundary conditions), the square of the amplitude of the function at any point is proportional to the probability of finding the electron at that point. Thus, the classical concept of simply locating a particle at a place in space and time has been replaced by a probabilistic description of its state. Note that the evolution of the wave function in time is deterministic. The probabilistic part of quantum theory arises when one interprets the wave function in terms of properties of particles.

In classical physics, a particle can get from "here to there" only if it has sufficient energy. For example, if an automobile is proceeding up a hill and the motor is stopped, the car will reach the top of the hill only if it has sufficient speed at the time of cessation of the engine's motive force, i.e., if the kinetic energy of the vehicle is not less than the potential energy difference between the top of the hill and the vehicle's present location (ignoring frictional losses). A more familiar example from these pages concerns the capability of various launch vehicles to place payloads into space. The cancellation of the Centaur G-prime as a high-energy upper stage for the Shuttle left the Galileo spacecraft with an energy problem in getting from Earth to Jupiter. A direct flight to Jupiter was not possible with the Shuttle/IUS combination, so Dr. Roger Diehl of JPL devised the VEEGA trajectory to obtain extra energy from three close planetary flybys.

In the world of quantum physics, the situation is different. The wave function for a particle extends, in many cases, indefinitely through space, transcending energy barriers. Therefore, a small particle, such as an electron, might be able to "tunnel" through an energy barrier some small fraction of the time - even if it could not surmount the energy barrier according to classical calculations. The electron does not ignore the barrier or is unaffected by it; the point is that the electron has some (small) chance to tunnel through it.

The STM functions by bringing the probing tip of the instrument close enough to the specimen surface-to-be-examined so that the wave functions of the elec-





The scanning tunelling microscope (STM), which is capable of resolution at the atomic level, produced this topographic map of a small section of a lead surface held at 4.2 degrees K ("Pb" is the abbreviation for "Plumbum," the Latin/chemical name for lead). Measurement scales in the diagram are in angstroms (Å). The 500 Å relief scale is to be applied directly in the plane of the paper to estimate the height of surface irregularities. Thus, an elevated ridge of a few hundred angstroms is apparent from this assembled set of scans (the STM can actually resolve to the single angstrom level). In the figure to the left the STM scans of the above figure have been coded with false colour to produce a second view of the lead surface. Blue denotes the lower elevations and the lead ridge is quite apparent. *JPL*

trons in the metals of these two objects (tip and specimen) overlap significantly. Then, when a voltage is applied across the gap, a small current will be able to "tunnel" its way through the (classically) non- conducting vacuum separating tip and surface.

In practice, a small current will flow when the tip is about 10 Å from the surface and a voltage of millivolts to a few volts is applied ("tip" is a somewhat misleading term, since the point has a radius of about 100 Å). The basic principle of operation is to adjust continually the tip/surface distance as the tip is scanned across the specimen surface in order to keep the tunneling current constant. Adherence to the principle of constant current insures that the tip/surface separation is constant. Hence, any moving up and down of the tip to keep the current constant is actually a measure of undulations of the surface being scanned.

The motion of the tip is controlled through the well-known piezoelectric effect; certain crystals change dimensions when a voltage is applied to them. This provides a very sensitive means of moving the tip through the small distances inherent in measuring surface topography at the atomic level (the voltage for piezoelectric control of the tip is, of course, distinct from the one being applied across the vacuum gap between tip and surface).

Resolutions at the level of about 0.1 Å are being achieved. Ultimately, 10^{-4} Å might be attainable over short scan arcs. The limit to resolution is set by the "shot noise" of electrons in the tunnelling current. For comparison, the so-called Bohr radius of the hydrogen atom is about 0.5 Å.

The piece of information obtainable through operation of the STM concerns the local composition of the specimen under study. By stopping the tip over a point of the surface and varying the applied voltage, a characteristic "fingerprint" of tunnelling current responses is obtained which is diagnostic of the material at the point. In this way, one can do spectroscopy at

the atomic level of surface structure, identifying impurities and other alterations in composition.

Atoms, the intellectual construct of Democritus in the fifth century BC, have moved in recent years from theory to direct observation; much as the planets of the ancients have swum into our ken through the prying eyes of spacecraft. Can the nucleus of the atom and the stars be far from our direct view?

Galileo Mission

After coming within four months of launch, the Galileo project was forced to regroup subsequent to the Challenger accident last year. Now, as described in recent editions of this column, the tide has turned, and significant steps have been taken toward an October 1989 launch: (1) a launch strategy was developed which substitutes an IUS upper stage and three planetary gravity assists for the cancelled Centaur high-energy upper stage for the Shuttle (*Spaceflight*, November 1986, p.404), (2) spacecraft modifications are well underway to permit an excursion into the inner solar system to receive the Venus gravity assist (*Spaceflight*, May 1987, p.218), and (3) the October 1989 Shuttle launch slot was confirmed by a joint NASA/ESA decision (*Spaceflight*, June 1987, p.229).

Robert Gershman, of JPL, is chief of Galileo Mission Design Team (MDT). After launch, his team will integrate the high-level science and engineering activities desired for the spacecraft and pass the products, termed Orbit Plans, to the Galileo Sequence Team for detailed implementation. The resulting sequences of spacecraft commands will be radioed to Galileo's onboard computer and each will serve to direct the mission for a period of time (between one day and one month). When one sequence is used up, another will be loaded into memory in its place. ***Spaceflight***, January 1987, p.40 furnishes a more extensive discussion of the process.

An important part of the integration task performed by the MDT is insuring that the Orbit Plan passed on to the Sequence Team of Galileo is free of conflict. There are a large number of rules that an Orbit Plan must adhere to in order not to conflict with Galileo systems represented by the spacecraft, ground stations, navigational plan, etc. For example, one must not attempt to play back to the Earth data from the spacecraft's tape recorder if, at the proposed time, inadequate coverage is available from antennae of the Deep Space Network.

The number of such rules (60) and the level of detail of the Orbit Plans (up to 2500 activities for an eight-day encounter period) make it impractical to rely upon purely human checking of the Orbit Plan, and a computer program MDCHECK ("Mission Design Check") is now under construction by an engineer and a programmer on the MDT. Gershman sees completion of this relatively complex piece of software as one of his team's most challenging tasks in the next year. Incidentally, checking for rule violations is by no means complete when MDCHECK has been executed. There are approximately 200 items in a sequence that need to be checked, and each item is assigned to a procedure or piece of software to insure compliance. Then, of course, all individuals involved in the sequencing process must truly remain alert to catch errors which seem to be covered by no particular rubric except Murphy's Law: "if something can go wrong, it will".

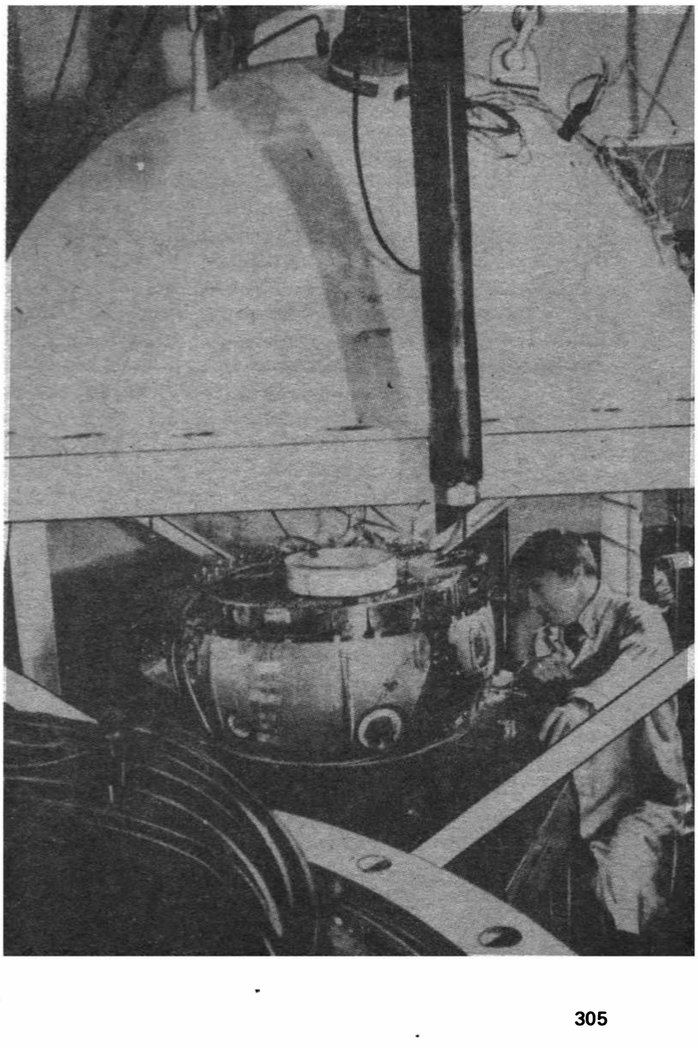
A second activity presently occupying the time of the MDT is the planning, in cooperation with other elements of the project, of details of the mission from launch (1989) to the end of activity in orbit about Jupiter (1997, or later).

In order to appreciate the flavour of any planning activity at JPL, it is necessary to understand the concept "requirement" as it is used in this context.

Formally, a requirement is a constraint or action levied by one project element upon another project element. One of the requirements placed by the Galileo Probe system upon the mission design is "the relative speed of the Probe at entry shall be less than 47.8 m/s." The requirement is footnoted to add precision by defining "relative speed" with respect to a uniformly rotating planetary atmosphere and "entry" as occurring at an altitude of 450 km above a precisely defined reference spheroid.

Viewed thusly, a requirement would seem to be a harsh, inflexible kind of thing such as one might expect to encounter in a legal contract. Indeed, your corres-

An engineer works on the Galileo probe during an early stage of its preparation. The probe will be released by the orbiter to plunge through the Jovian atmosphere.



pondent recalls, several years ago, having a very difficult time trying to elicit from a non-JPL scientist a presumably simple environmental parameter for an instrument he planned to fly. After some rather puzzling, to me, verbal exchanges, it turned out that my use of "requirement" had done the mischief. The inflexibility he read into this word made him want to defer mentioning a numerical value for the parameter lest it be seized and graven, once and for all, into stone.

The truth is that a "requirement," in the sense we use the term, can be met, may fail to be met, can be changed, or may even be scorned ("I'll write it down, but there is no way that silly requirement can ever be met"). The virtue of having a *patois* based upon requirements is the clarity, through being explicit, that is introduced into the process. It is the engineer's attempt to bring the rigor of the mathematician to his subject. The ultimate fate of any requirement is determined by negotiation and common sense.

In March of 1987, a new set of mission requirements was issued by the MDT to reflect the present state of evolution of the mission. In a sense it is the team's manifesto and allows other project teams to carry forward their planning (or to object if they see an errant requirement). It is instructive to review the major events of the Galileo mission and to present, in a very selective fashion, some accompanying requirements on the design of the mission. During operations, a separate, but related, set of requirements applies. In this way, one can obtain an overview and a feel for some of the detail of the undertaking. A modern space mission is a complex web of relationships.

The nominal Galileo launch period extends from October 8 through November 24, 1989. The launch vehicle will be the Shuttle Atlantis with an IUS for injection into interplanetary space. The mission system places, for example, a requirement on the launch-vehicle system to provide telemetry coverage at 1200 bits per second for five minutes during IUS burns, with no more than a one minute outage. But the requirement is softened to avoid over constraining launch sequence design. That is, one would probably not want to scrub injection because of an anticipated 90-second telemetry outage. Of course, some requirements, safety-related ones in particular, allow no such latitude.

Approximately 100 days after launch, the spacecraft will fly closely past the planet Venus in order to receive a gravity assist toward its ultimate Jovian destination. Looping through the inner solar system, it will receive a second gravity assist, from Earth (about 400 days after launch). The third, and final, gravity assist (from Earth) takes place about three years after launch, and the spacecraft then proceeds on a direct flight to Jupiter.

Approximately 150 days before closest approach to Jupiter, the atmospheric Probe will be released toward its target. Requirements on the navigational system state that, with 0.99 probability, the absolute time of entry of the Probe shall be controlled to within ±8 minutes and the latitude of its entry point controlled within ± 0.5 degrees. Seven days after release of the Probe, the spacecraft (now called 'Orbiter', in recognition of its intended use) will perform a manoeuvre to place it on a course that will allow it to overfly, for communication purposes, the Probe during its entry and descent through the Jovian atmosphere.

The period of time surrounding entry into orbit about Jupiter is occupied by three critical events: (1) a close flyby of the satellite Io six hours before entry into Jovian orbit in order to make scientific observations and to receive a gravity assist that will reduce the size of the orbit insertion burn, (2) reception and relay to Earth of Probe scientific data by the Orbiter for up to 75 minutes, as the Probe descends through the atmosphere, and (3) ignition of the Orbiter's engine 45 minutes after completion of receipt of data from the Probe, complementing the Io gravity assist and placing the Orbiter into an orbit about Jupiter with a period of approximately 230 days. This sequence of events is so critical that it will be tested in the spacecraft's computers before launch (a corresponding test was done on the spacecraft before the originally planned launch in May of 1986) and demonstrated in flight after Probe release (with no main engine burn). A second example of a Probe requirement on the mission is: "The Orbiter-Probe relative geometry shall be such that during the relay the Probe-to-Orbiter radio signal does not pass through the Jovian rings." This seems obvious, once somebody thought to write it down.

In addition to Probe entry, several other unique observational opportunities occur on arrival day: Io close encounter, "ground truth" Probe entry-site observations by the Orbiter, and occultations of the Sun and Earth by Jupiter. Gershman and his Mission Design Team are now coordinating an extensive effort by many elements of the project to select a Jupiter arrival date for Galileo which optimises observational geometry and Deep Space Network coverage for these opportunities. Arrival-date selection also affects such diverse attributes as asteroid encounter opportunities on the way to Jupiter and the remaining amount of propellant available during the subsequent tour of the Galilean satellites.

At the farthest point from Jupiter ("apojove") in this first orbit, a large manoeuver is done in order to raise the altitude of the next, impending perijove (closest approach to Jupiter). Although the spacecraft systems have been designed to withstand the radiation from the intense Jovian belts during entry into orbit, repeated exposures close to Jupiter could prove harmful to the electronics. Hence, Io, the inner of the four Galilean satellites, will be visited at close range only once, during the gravity assist. "The trajectory design shall ensure a radiation design margin of not less than 2 after completion of five revolutions and not less than 1 after the completion of the whole nominal satellite tour...," and the requirement goes on to specify the details of the radiation design assumptions.

The satellite tour itself consists of repeated encounters with the three other Galilean satellites, Ganymede, Europa, and Callisto, with ten close encounters taking place in a period of 22 months. Also, a large orbital excursion will send the spacecraft to explore the tail of the Jovian magnetosphere.

During the tour it is necessary to recognise that finite resources exist on tne ground, and the following requirement reflects this fact: "Changes in satellite aim points and times of closest approach due to changing science desires shall not be accepted later than the start of Orbit Plan development for the first orbit in which such a change occurs."

Let us close with a requirement that is also phrased in the form of a limitation but really conveys something of the great scope of Project Galileo: "A maximum of 50,000 images shall be permitted." What a treasure chest of photography that will constitute! Any bets on the fate of the design requirement if image number 50,001 looks to be exciting?

SEPTEMBER 1987 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

Space at JET PROPULSION LABORATORY JPL

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DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH, England. Tel. 0344 884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L. Ltd., Aylesbury, Buckinghamshire, England.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 29 No. 9 September 1987

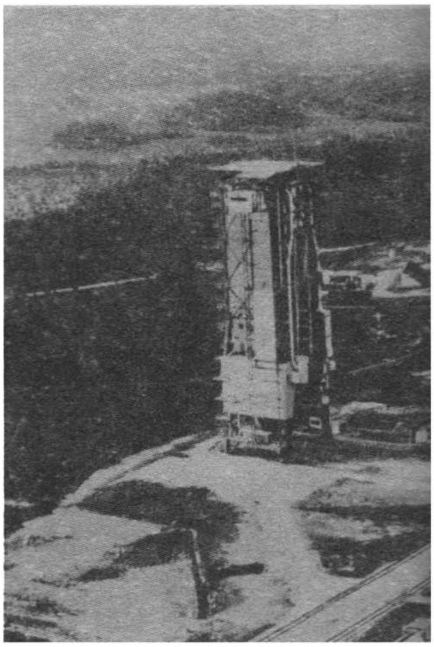
Front Cover: The STS-9 Spacelab 1 crew take a break from their very full work schedule to pose for this unusual zero-gravity group photograph. Clockwise from the lower right are: Payload Specialist, Byron K. Lichtenberg; Mission Specialist, Dr. Robert A. Parker; Mission Commander, Capt. John Young; Payload Specialist, Ulf Merbold of the Federal Republic of Germany, the first European to fly on a US Space Mission; Mission Specialist, Dr. Owen K. Garriott: Mission Pilot, Brewster Shaw. STS-9 was launched on November 28, 1983 and carried out a 10-day mission. Following the Challenger accident, plans for further flights of Spacelab, after the resumption of Shuttle launchings, have been drastically reduced. The question 'Has Manned Space Flight A Future?' opens a special 10-page feature on Manned Space Flight beginning on p.325.

В журнале не печатается ряд страниц.

EUROPEAN RENDEZVOUS

Ariane Launcher in Operation

The directors of Arianespace, the world's first industrial and commercial space transport company, have every reason to be confident about the future. Despite a break of well over 12 months in the Ariane launch schedule, the company has showed a substantial increase in its 1986 pre-tax profits and secured a further 18 launch contracts in its order book. So far in 1987 another four satellites have been registered for launch by Ariane, making a total of 63 satellites, 14 of which have already been placed successfully in orbit. Mission V19, the first since last May's failure, is now scheduled for the middle of this month (September), although Arianespace remains understandably cautious and will postpone the launch should any major problems arise.



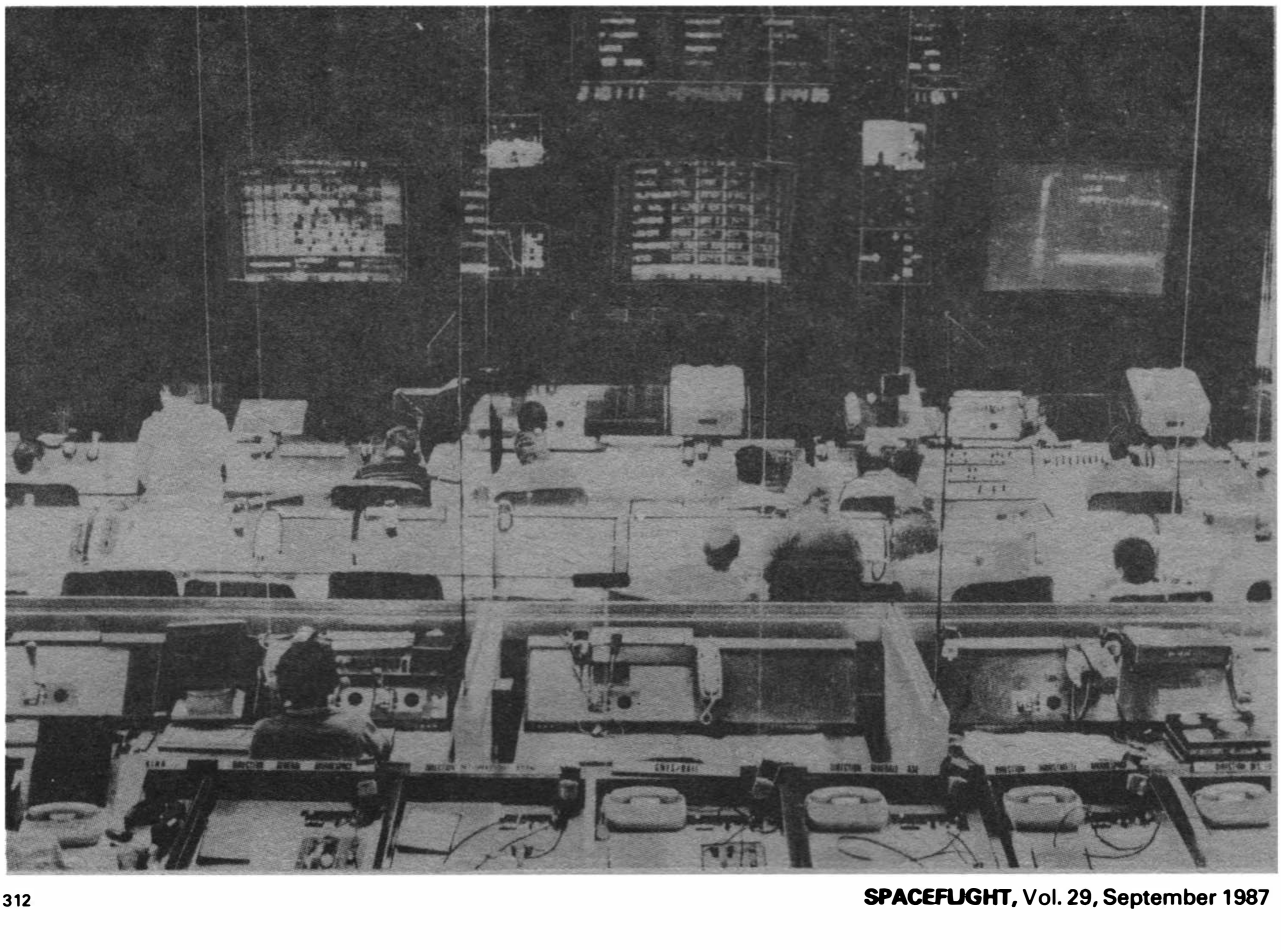
Annual Report

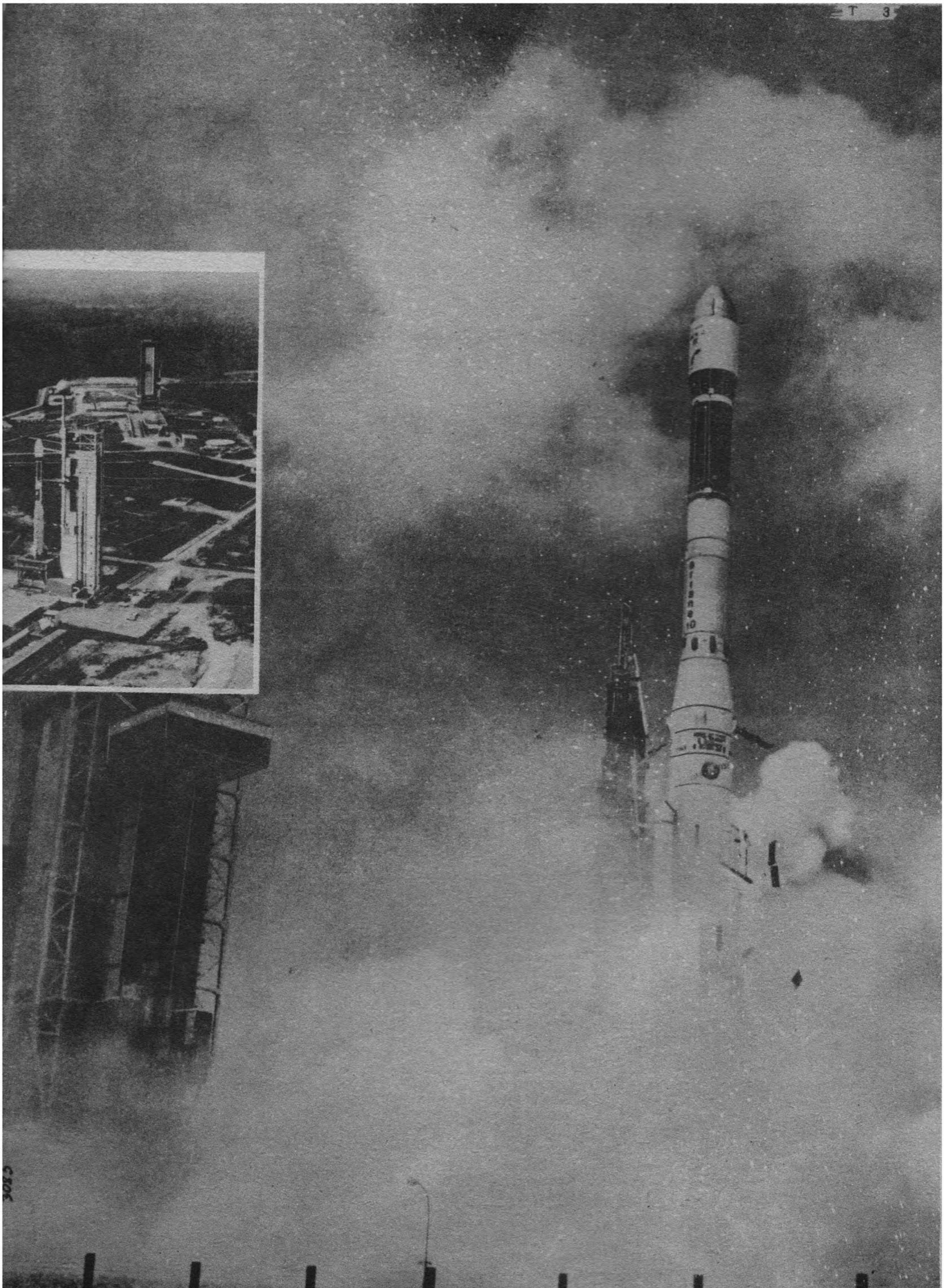
Of the six planned launches for 1986, three were accomplished. After the successful orbit injection of the satellites Spot/Viking during flight V16 (February 21, 1986), G-STAR II (American) and SBTS 2 (Brazilian) during flight V17 (March 28, 1986), the third stage cryogenic engine had a problem during the ignition phase, leading to the loss of the Intelsat V F14 satellite on flight V18 (May 30, 1986).

Fourteen recommendations were formulated by a six member commission of enquiry into the failure and all have been taken into account by technicians with the responsibility of correcting the problems of flight V18 and consolidating definition of the third stage engine concerning ignition and the turbopump bearings.

By the end of last year, 32 simulated altitude tests had been completed leading to the choice of a new ignitor

Launch of flight V10 in August 1984 (opposite). The Ariane 3 version, carrying two communications satellites, is the same as that for mission V19. The inset picture (above right) is an aerial view of the ELA 1 and ELA 2 launch pads. An Ariane 3 launcher is being prepared on the ELA 2 pad which was used for the first time in March 1986. Monitoring of Ariane launches takes place in the 'Jupiter' control room (below) at the Guiana Space Centre. *Arianespace*





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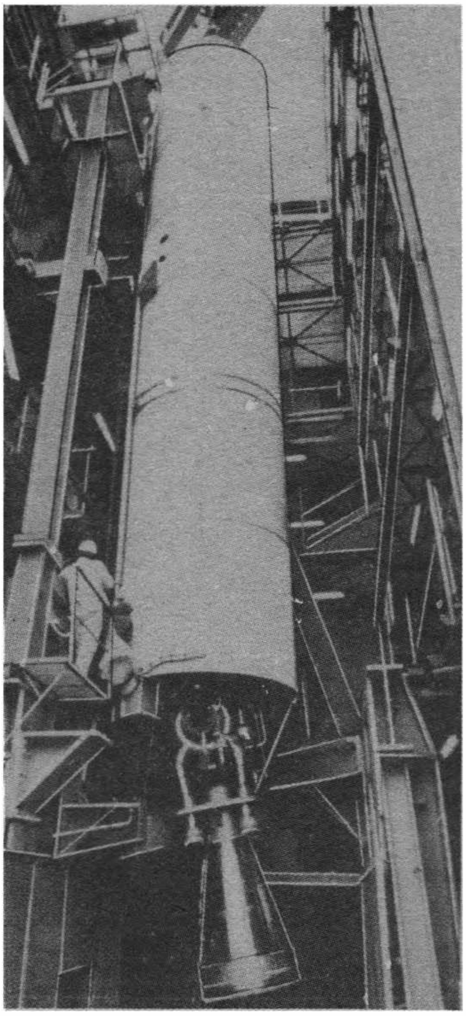


Liquid propellant booster for the Airane 4 launcher. *Arianespace*

Flight	*Month*	*Vehicle*	*Payload*
		1987	
V19	Aug	Ar 3	AUSSAT K3 & ECS 4
V20	Oct	Ar 2	TVSAT 1
V21	Dec	Ar 3	G STAR III/GEOSTAR R01 & TELECOM 1C
		1988	
V22	Jan*	Ar 4	APEX 401 : METEOSAT P2, AMSAT & PANAMSAT
V23	Mar	Ar 2	INTELSAT V F13
V24	Apr	Ar 2	TDF-1
V25	May	Ar 3	SPACENET IIIR, GEOSTAR R02 & SBS 5
V26	Jun	Ar 3	EC5 & INSAT 1C
V27	Sep	Ar 4	ASTRA 1 & MOP 1
V28	Oct	Ar 2	INTELSAT V F15
V29	Nov	Ar 4	TELE-X** & SKYNET 4B

* *Decision to launch ARIANE 401 between Flights 21 & 23 or between Flights 20 & 21 will be made later on*
** *In the event that SSC decided to schedule TELE-X on another launch, JC-SAT will have priority on Flight 29*

		1989	
V30	Jan	Ar 3	OLYMPUS
V31	Feb	Ar 2	JC SAT & DFS 1
V32	Mar	Ar 2	SPOT 2
V33	Apr	Ar 4	SUPERBIRD-A & HIPPARCOS
V34	May	Ar 4	INTELSAT VI F1
V35	Jun	Ar 4	SUPERBIRD-B & INMARSAT 2 F1
V36	Sep	Ar 4	TDF-2 & DFS 2 (or INMARSAT 2F2 or GSTAR IV/GEOSTAR TR1)
V37	Oct	Ar 4	SATCOM K3 & INMARSAT 2 F2 (or DFS2 or GSTAR IV/GEOSTAR TR1)
V38	Nov	Ar 4	INTELSAT V1 F2
		1990	
V39	Jan	Ar 4	EUTELSAT IIA & MOP 2
V40	Feb	Ar 4	TVSAT 2 & GSTAR IV/GEOSTAR TR1 (or DFS 2 or INMARSAT 2F2)
V41	Mar	Ar 4	EUTELSAT II B & SKYNET 4C (or ERS 1)
V42	Apr	Ar 4	INTELSAT VI F3 (or ANIK E1)
V43	May	Ar 4	ERS 1 (or EUTELSAT IIB & SKYNET 4C)
V44	Jun	Ar 4	ANIK E1 (or INTELSAT VI F3)
V45	Sep	Ar 4	EUTELSAT IIC & ITALSAT 1
V46	Oct	Ar 4	SATCOM K4 & GEOSTAR II
V47	Nov	Ar 4	ANIK E2

configuration and new ignition sequence. (***Spaceflight***, February 1987, p.57). This year has seen the total rise to 41 simulated altitude tests on four engines with 19 of them in the V19 flight configuration, and 13 tests on five engines in the V19 flight configuration.

The delay in launches has been used to general advantage in reviewing Ariane systems and in particular for refining the operation of the third stage engine turbopump bearings.

Arianespace has maintained production at a steady rate for all the launcher elements which have not been affected by the third stage ignition problem. In this way, the first and second stages, as well as the fairings and equipment bays, have been regularly produced albeit at a reduced rate to limit storage problems.

Financial Results

Arianespace accounts for 1986 showed a turnover of FF 1,289 million and net profits amounting to FF 259 million, compared to FF 208 million in 1985.

The 18 new launch contracts, valued at around FF 6 billion, cover the launch of five European, four American, two Japanese and one Indian spacecraft, as well as six satellites for international organisations. Eight of these customers choose Ariane for the first time.

Since the creation of Arianespace in 1980, 31 launchers have been ordered from the European space industry (in addition to the 10 Ariane 1 launchers ordered by ESA). Of the 31 launch vehicles, eight have already flown, 23 are in production (five of them partially delivered and stored in the Aerospatiale centre at les Mureaux). These 23 launchers represent a sales value of about FF 10 billion for the European space industry, and are made up of 10 Ariane 2/3s and 13 Ariane 4s.

Ariane 4, capable of launching satellites weighing two tons, will be the workhorse of Arianespace for the next ten years. The first launch of this version is scheduled before the spring of next year.

Adaptability of the Ariane launcher results from modular design of the first stage, giving optimum adjustment of performance and a range of possibilities for using the payload volume inside the nose fairing.

Thus, the Ariane 3 launcher is derived from Ariane 1, incorporating a series of modifications which increase the weight that can be placed into geostationary orbit from 1825 kg to 2580 kg. The Ariane 3 launcher has three stages, with the first incorporating two boosters, ignited just after lift-off.

The Ariane 2 version is identical to Ariane 3, but without the extra boosters.

Ariane 4 offers six variants for single or dual payload configuration launching of a wide range of satellites with mass values of between 1900 kg and 4200 kg.

It differs principally from previous members of the Ariane family by the nature of the boosters used. These can be:

EUROPEAN RENDEZVOUS

- Two or four solid propellant boosters derived from those used in the Ariane 3 version.

- Two or four liquid propellant boosters carrying approximately 40 metric tons of fuel and using the Viking engine.

- A hybrid version with two solid propellant and two liquid propellant boosters.

- A variant with no boosters.

This choice of configurations provides a wide degree of flexibility, giving Arianespace the ability to adjust launcher performance to individual payloads.

Following Ariane 4 will be a completely new configuration – Ariane 5 – a launcher that will be capable of putting up to 5800 kg or the planned Hermes manned spaceplane into Earth orbit.

Insurance

During 1985/6 the space insurance market experienced a loss exceeding US$400 million and as a result insurance premiums are almost as large as the cost of launch. For example, a customer wanting to launch a 1200 kg satellite will have to pay about US$45 million for launching proper and US$20 to 25 million for its insurance.

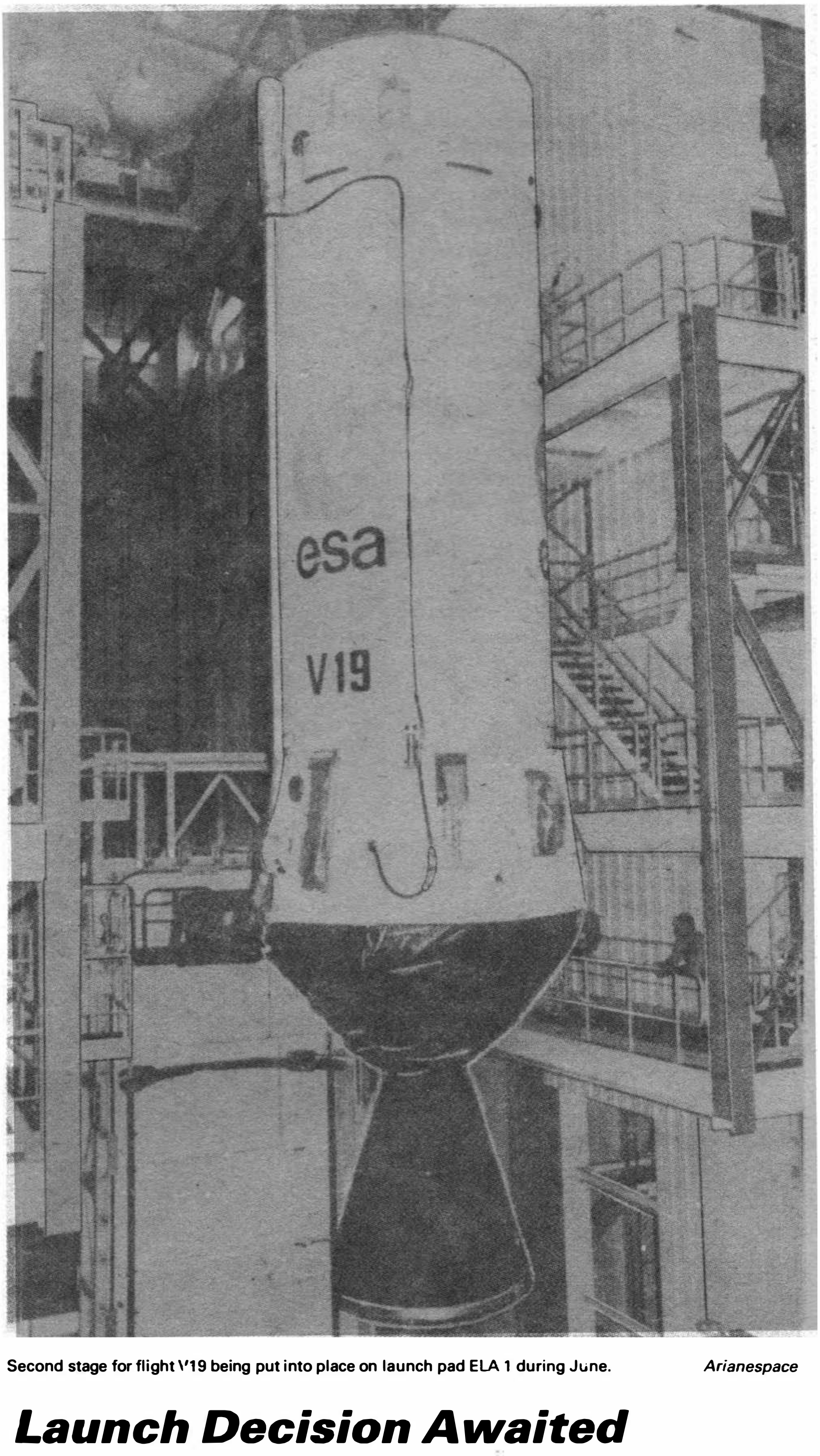
Facing up to the problem, Arianespace decided the most critical risk is during the launching phase when Ariane transports two satellites simultaneously. The "risk accumulation" problem can then be defined in terms of available capacity because when the two satellites are separated from the launch vehicle the risks are independent and the capacity available on the market is nearly sufficient.

To create a new available capacity to cover the launching phase, Arianespace considered a series of launchings rather than solving the problem on an individual basis.

The organisation of a system based on a series of 15 launchings, not mandatorily successive, permits offering Arianespace customers a "launch risk guarantee" for launchings scheduled within three years.

S3R, a 100 per cent Arianespace subsidiary which started operation in January 1986, manages the new insurance plan which has so far been taken up by 15 clients with many others taking a strong interest.

"The launch risk guarantee" is aimed at covering a part of the financial risks run during the Ariane launch phase (the period between the opening of the launch table clamps and the satellite separation following injection into geostationary transfer orbit). Payment schedule for this supplementary service follows that of the main contract and the price is fixed at the outset.



Second stage for flight V19 being put into place on launch pad ELA 1 during June. *Arianespace*

Launch Decision Awaited

A final decision on whether to go ahead with the launch of mission V19 on September 11 was expected from Arianespace at the end of last month (August).

Following a series of successful tests the redesigned third stage motor has been fitted to the Ariane third stage. Further tests on two identical motors were being carried out and if positive clearance for launch was expected.

The V19 mission is due to put the Austrialian Aussat K3 and European ECS-4 communications satellites into orbit. If everything goes well with the launch two further misisons are planned before the end of the year.

EUROPEAN RENDEZVOUS

Space Plan Flounders

Future British space plans were thrown into turmoil this August after the resignation of Roy Gibson, Director-General of the British National Space Centre. His decision followed the Government's rejection of the BNSC's forward-looking space plan, which would have put the UK on a par with other major European nations, and the refusal to provide funds needed urgently by British firms involved in research on various European projects.

Commitment to Space

When Roy Gibson was appointed head of the newly formed British National Space Centre in November 1985 there was a new mood of optimism throughout the UK space industry.

It was well founded. Mr. Gibson (62) brought a wealth of experience and international standing to the previously fragmented British space effort.

He was one of the principal architects of the European Space Agency and became the first Director-General on its inception in 1975. After leaving ESA in 1985 Mr. Gibson was a consultant to and director of several UK and multi-national space companies.

Given such a background, Mr. Gibson's appointment as leader of the fledgling BNSC was seen as an obvious commitment by the British Government to space.

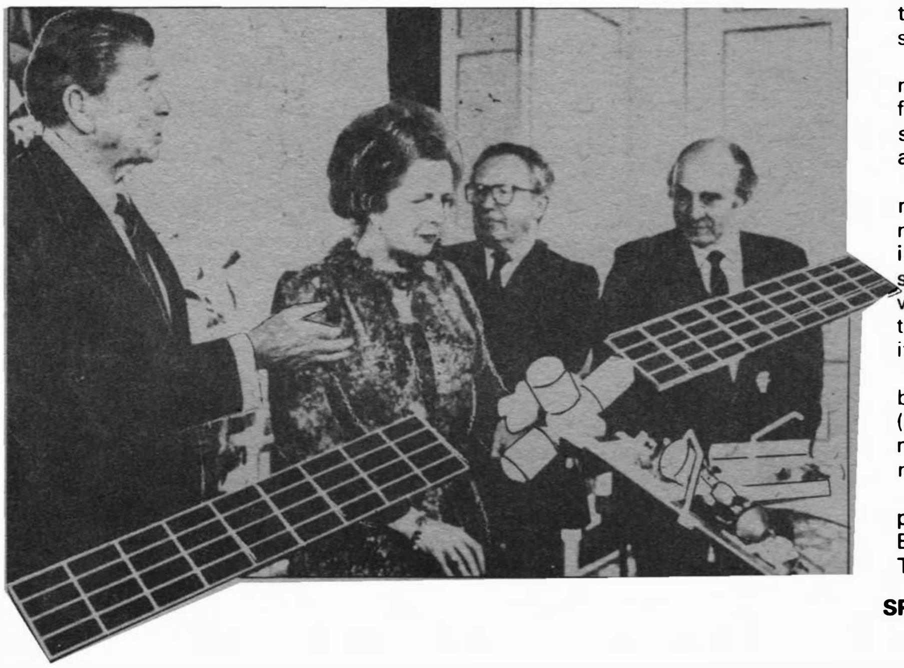
Sir Geoffrey Pattie, the Government minister then responsible for space activities, described it as "a very important time" for the British space industry when he announced the appointment on November 20, 1985.

"It is a clear recognition in Government circles of space as a leading-edge technology generator. This is an exciting area for Britian to be involved in," he said.

Sir Geoffrey Pattie.

Writing in ***Spaceflight*** (April 1986, p.156), Sir Geoffrey, who lost his cabinet position as Secretary of State for Trade and Industry following the general election this June, said: "The establishment of a national space centre does not signal a new direction in our space policy in Britian. Rather it emphasises the Government's commitment to the development of space technology for industrial, scientific and defence purposes."

Margaret Thatcher and President Reagan study a Space Station model during the June 1984 economic summit in London. Mrs. Thatcher gave her support for the international space station.



Twenty months later the BNSC was plunged into a crisis. Mr. Gibson's resignation was announced in a brief statement issued by the Department of Trade and Industry late on August 4. It will take effect from the end of this month (September 30) when Mr. Gibson will leave the Civil Service. Mr. Jack Leeming, his present deputy, will take over as acting head of the BNSC until a permanent successor is appointed, probably in the new year. A special meeting to discuss the future of BNSC is due to take place during the first week of this month.

Space Plan

Part of Mr. Gibson's brief when he took the helm of the BNSC was to produce a national space plan to take the country forward into the next century.

The 15-year plan first went before the Cabinet last autumn but was subjected to a protracted dragging of heels, despite the impending European ministers' meeting in June (now postponed until November) when decisions were needed on UK participation in various European projects, including Ariane 5 and the Columbus space station.

Finally, on July 24 this year the Prime Minister, Mrs. Margaret Thatcher, told MP's in the House of Commons that the Government was unable to find anymore money to fund the expansion called for in the UK space programme.

Details of BNSC's space plans were not openly published but the crux was for a three-fold increase from the present £112m to an annual budget of around £300m.

Five key areas identified for investment were: launch vehicles, the international space station, remote sensing, space science and communication satellites. One of the aims of the plan was to increase the UK's contribution to ESA to a level comparable to that of its partners with a similar GNP.

The UK's £100m a year space budget compares with France's £700m (to be increased to £900m) and Germany's £3-500m. Italy, and even India, now spend more on space than Britain.

Higher investment in ESA space programmes would have allowed Britian to take a lead in some projects. The Columbus Space Platform for

EUROPEAN RENDEZVOUS

Comment

Roy Gibson

In November 1985, the separate branches of Britain's space activity were brought within the management structure of the newly-formed BNSC. Many factors augured well for the success of the new organisation, the move being recognised as long overdue and indeed necessary if Britain was to hold its place internationally in space affairs.

The appointment of Roy Gibson as its first Director-General gave Britain a new authority among its European partners, who recognised Mr. Gibson's standing from his service as the first Director-General of ESA during which the organisation was largely created in its present form. Now at BNSC, his mandate was to develop a strong, co-ordinated UK space policy embracing the work of Government departments, research establishments and industry.

It soon became clear that the BNSC was fulfilling a much needed role among previously departmentalised space interests. The Centre was found to be approachable and effective in promoting a new level of communication and liaison over the whole spectrum of space activity from the academically scientific to the commercially entrepreneural. It was also clear that this was due in no small measure to the quiet style and energetic contribution of the man at the top, Roy Gibson. In a relatively short time (by July 1986), he had coordinated Britain's space participants and evolved a future space plan for Britain.

In contrast to BNSC's positive actions and detailed analyses for Britain's future in space, the Government's reception of the plan over the last year has been unresponsive, noncommital, discouraging and finally dismissive. Many might well now ask whether setting up the BNSC and the formulation of the Space Plan was an unfortunate accident – a glaring example of wasted opportunity and personal talents. Roy Gibson has made his position clear by resigning from his post. In this, he takes with him the understanding, respect and appreciation of the many people who have seen his efforts at the BNSC and gladly associated with him.

Earth observation is one example and the Hotol spaceplane another. Now, there is little chance that the UK, contributing at such a low level, will be able to presuade ESA members to contribute to a British-led project.

Part of the Government's reluctance to approve even a modest increase in space spending stems from its desire to contain research and development within current limits.

During Question Time in the Commons before MP's went on their summer recess, Mrs. Thatcher defended the Government's attitude.

"We spend some £4.5 billion on research and development. We are not able to find any more resources without switching funds from one research or technology development to another," she said.

"We feel we cannot make the switch. We shall continue our subscription to the European Space Agency but at present we are not able to find any more money."

It is Mrs. Thatcher's view that money to finance space research should come from the private sector.

ESA Meeting

At the end of July the Government announced the formation of a new Cabinet Committee, chaired by Mrs. Thatcher, to examine all aspects of spending on research and development. Mr. Kenneth Clarke, the minister responsible for space, will be seeking a mandate from this committee to take to the ESA ministerial meeting this November.

Postponement of the meeting from June meant the BNSC had to find an extra £6m to £9m to enable various UK companies to continue working on current ESA contracts until November.

Jack Leeming.

However, a BNSC request for cash was refused by the Department of Trade and Industry leaving Mr. Gibson and the firms involved in an uncompromising position.

Higher Investment

A warning that Britain would lose out unless it invested more in space technology came from Professor Reimer Lust, Director-General of ESA, during a visit to the UK in the first week of August.

He said it would be his duty to advise member states that decisions have to be taken regardless of whether the UK is in a position to participate or not.

Criticism of the Government's decision on space funding mounted rapidly. The United Kingdom Industrial Space Committee, meeting on August 6, accused the Government of undermining the confidence of the aerospace and electronics industries involved in space.

Mr. Chris Darke, national organiser of the technical union, TASS, said: "The Government hope that private industry will fund future space ventures cannot be taken seriously.

"Most of these, such as the revolutionary space plane Hotol not only require large amounts of finance, but are technological leaders to the extent that much risk is involved. Historically, private industry is slow to finance such innovation".

British Aerospace, approaching the final stage of its proof of concept studies on Hotol this month, also warned that the UK could be left out.

"We believe that there are certain commitments for the UK on Hotol and the space platform. At present it is unclear as to how these commitments can be met," said a company spokesman.

A low level of investment in space research could lead to countries like France or Germany taking over major development work on innovative projects like Hotol, with UK companies being left as small sub-contractors.

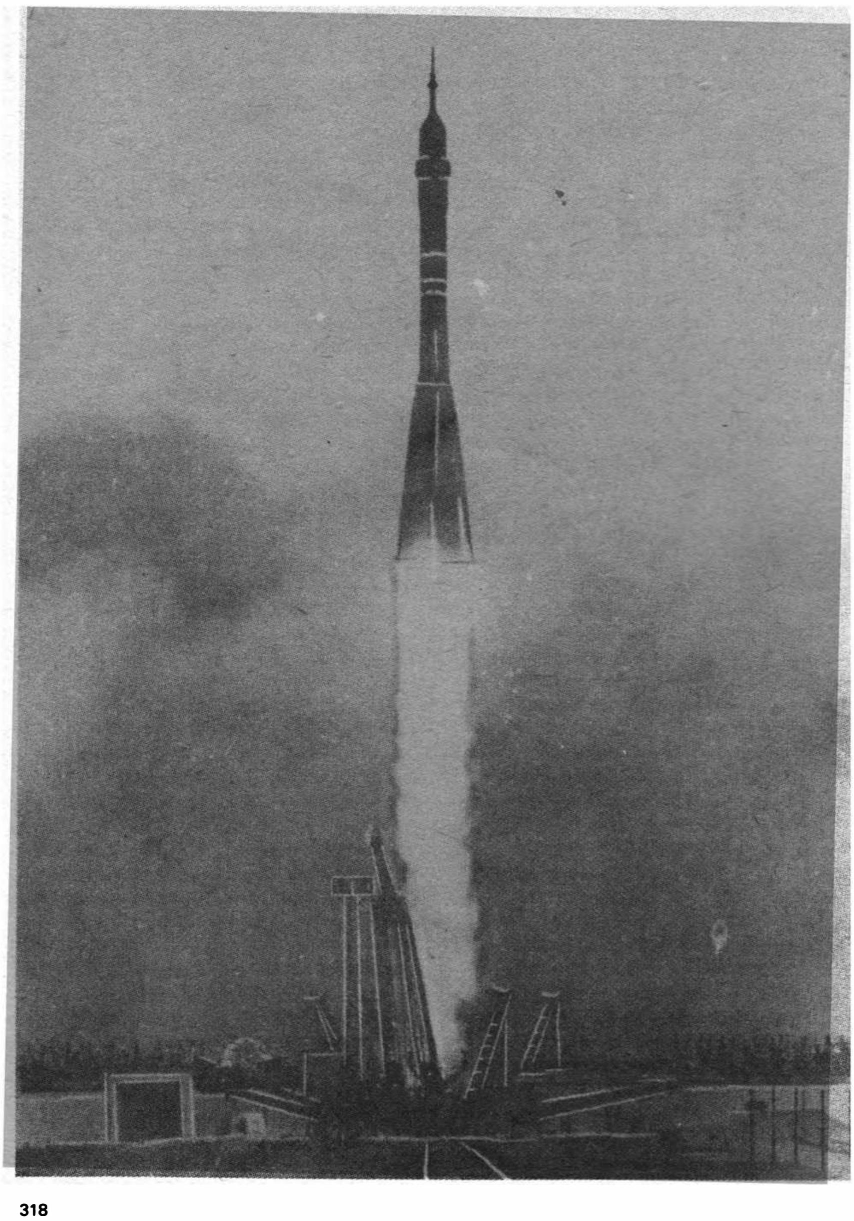
INTERNATIONAL SPACE REPORT

A monthly review of space news and events.

Major Launches Consolidate Soviet Lead

Soviet activities continue to dominate the world space scene. Two major launches occurred in July – the Soviet-Syrian crew to the Mir space station and a new unmanned observation platform, larger than any previous Earth resources satellite. Our first report of the latest manned mission to Mir (see below) will be followed by a more detailed analysis in a subsequent issue.

Launch of Soyuz TM-3 on July 22 from Baikonur carrying the Soviet-Syrian crew. *Novosti*



The international space crew of Alexander Victorenko, Alexander Laveikin and Syrian cosmonaut Mohammed Faris returned to Earth from the Mir orbital complex on July 30, leaving Yuri Romanenko and Alexander Alexandrov on board.

Their Soyuz TM-2 descent module landed an hour after dawn 140 km north-east of the town of Arkalyk, Kazakhstan. The cosmonauts were all well.

Helicopters were on site to welcome them home, four hours after they had bid farewell to Romanenko and Alexandrov, bolted the transfer hatch and undocked from the Mir space station.

A high wind dragged the descent module, hanging from its parachute, towards a village amid the fields below. It came down in a cloud of yellow dust, braked by its landing engines, two kilometres from the nearest buildings.

Victorenko and Faris lounged comfortably in their seats as a group of medics stood over Laveikin, who had spent over half a year in zero gravity. Looking slightly pale, Laveikin braved his "weighty" situation with a smile. Concern by doctors over unexpected readings from his heart had led to his replacement in the main crew by Alexandrov.

After a brief news conference in the fields, surrounded by friends and local farmers, the crew flew to Arkalyk by helicopter, and two hours later at the Baikonur Cosmodrome were given the traditional Russian welcome of bread and salt.

Victorenko, Faris and backup flight engineer Victor Savinykh spoke to reporters at the Baikonur Cosmodrome. Laveikin was still under special medical care, but his heath was not a source of concern.

Doctors said their clinical examination of Laveikin had revealed no problems. The abnormalities in the functioning of his heart, discovered during the flight, had been treated. They will

INTERNATIONAL SPACE REPORT

Alexander Laveikin

Cosmonaut Alexander Alexandrov (44) who has replaced Alexander Laveikin on board the Mir space station. Alexandrov made his first flight aboard the Soyuz T-9/Salyut 7 complex in 1983. *Novosti*

carry out more research at the national heart research centre to find out the cause.

Alexander Victorenko, asked why he had adapted to space so quickly – within the first hours of the flight – believed it was the result of ten years of training. He observed that Mohammed Faris has also adapted relatively quickly and was working on the second day.

Laveikin later recalled that the first crews to spend months in space had had to pay a higher price for the return to gravity, and praised the developments achieved by the doctors.

"I would certainly like to carry on the work. I felt well during the flight. I felt great throughout. But you can't argue with the doctors," he said.

Government Meeting

A special meeting of the Syrian government described the joint space mission which enabled the first Syrian to go into space as "an outstanding event in the history of Soviet-Syrian relations".

The cosmonauts brought back with them results of several experiments and photographs of Syria for use in studying the country's natural resources.

Much information was also gathered on physical processes in the upper layers of the Earth's atmosphere and in the ionosphere.

Launch and Docking

Soyuz TM-3, with its international Soviet-Syrian crew, was launched from Baikonur on July 22, docking successfully with the Mir space station two days later.

The two cosmonauts who had been aboard Mir since February 6, Yuri Romanenko and Alexander Laveikin, welcomed the first Syrian in space, Mohammed Faris, and his colleagues Alexander Alexandrov and Alexander Victorenko.

Soviet TV viewers saw a live telecast from space which showed the crucial moment of docking. Mohammed Faris was seen to greet the men on Mir with the words, "Dobroe Utro (good morning), Salam."

Victor Blagov, deputy mission controller, reported that it was the first time that a manned spacecraft had docked with the Mir station using the port on the Kvant astrophysical module.

Soviet Earth Survey Platform

The largest civilian Earth survey spacecraft ever launched was put into orbit by the Soviets on July 25.

Weighing between 15 and 20 tons, the Earth resources/ocean survey platform was launched by the Proton booster.

According to the Soviets, the spacecraft, designated Cosmos 1870, carries multi-disciplinary science instruments that will provide information for hydrology, cartography, geology, agriculture and the environment.

The platform, similar to but larger than the US Earth Observing System planned for launch in 1996, will supply the newly formed Soyuzkarta organisation with data for sale world-wide. As such it will compete with the US Landsat and French Spot satellites in an area of space development that is likely to expand dramatically by the end of the century.

Soyuzkarta has been set up by the Soviet Department of Geodesy and Cartography to sell photographs of the Earth taken from space.

According to Victor Yatsenko, department chief, the smallest resolution obtainable in pictures taken from Mir is six metres.

"Quite a few countries have sent in requests for space photographs of their territory. These include Australia, Kuwait, Angola, North Korea, Vietnam and the German Democratic Republic," said Yatsenko.

A training centre has been set up in Dushanbe, Tajikistan, to teach foreign specialists how to interpret space photographs.

Space Medicine...

New materials to be used in preparing medicines to fight many serious diseases, are being produced aboard Soviet manned and unmanned spacecraft.

Less than eight hours after the return to Earth of Cosmos 1841 on May 8 (launched April 24, 1987) various preparations from the satellite were at the Institute of Biomedical Technology in Moscow. They were produced in the Kashtan automatic unit.

Alpha-1 Thymosin was produced in a thymus hormone purification experiment. Thymosin can be produced in laboratories on Earth but it lacks the purity of a space-produced sample.

Another orbital preparation of the interferon type is being used in the Soviet Union for the treatment of viral and tumour diseases.

Space Missions...

During a recent visit to Austria of a delegation led by Mikolai Ryzhkov, the Soviet Prime Minister, the possibility fo a joint Soviet-Austrian space mission was discussed. Arrangements for a possible Soviet-Afghan space flight are also making progress.

Space Tests...

The Soviet Luch communications satellite capable of handling 30,000 to 40,000 channels is being tested at the Intercosmos communications centre near Moscow, by countries involved in the joint project.

Czechoslovakia provided the receiving station; Hungary, Poland and the German Democratic Republic designed the measuring and tracking equipment, and Bulgaria the transceiver used in the satellite to pick up and rebroadcast signals.

Already communications channels between the countries have been upgraded and use of digital systems will now more than double the facilities available.

Space Scientist...

Mikhail Ryazansky (78), a space scientist who supervised the creation of radio control systems for Soviet rockets and spacecraft, died in Moscow recently.

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST — 205

Robert D. Christy

Continued from the August 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1843, 1987-39A, 17940.
Launched: 0915, 5 May 1987 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. Overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 347 x 415 km, 92.21 min, 70.38 deg.

GORIZONT 14, 1987-40A, 17969
Launched: 1445, 11 May 1987 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad.
Orbit: Geosynchronous above 140 deg east longitude.

COSMOS 1844, 1987-41A, 17973
Launched: 0546, 13 May 1987 from Plesetsk by D-2?
Spacecraft data: Not available.
Mission: Possibly electronic intelligence gathering.
Orbit: 849 x 853 km, 101.99 min, 71.01 deg.

COSMOS 1845, 1987-42A, 17975
Launched: 0600, 13 May 1987 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. Overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 348 x 415 km, 92.21 min, 70.39 deg.

USA 22-25, 1987-43A, E, F & G
Launched: 1600, 15 May 1987 from Cape Canaveral AFS by Atlas H.
Spacecraft data: Not available, but USA 22 was the parent vehicle for USA 23, 24 & 25 are probably joined together by several-kilometre-long wires.
Mission: Ocean surveillance using radar
Orbit: 1050 x 1170 km, 107.5min, 63.4 deg.

PROGRESS 30, 1987-44A, 17999.
Launched: 0402*, 19 May 1987 from Tyuratam by A-2
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 700 kg.
Mission: Unmanned cargo vessel flying in support of the Mir space laboratory complex. It docked with Kvant's rear port at 0553 on 21 May.
Orbit: Initially 186 x 246 km, 88.76 min, 51.63 deg, then manoeuvred to 343 x 366 km 91.60 min, 51.63 deg for docking with Mir.

COSMOS 1846, 1987-45A, 18004.
Launched: 0915, 21 May 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. Overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 323 x 342 km, 91.25 min, 82.36 deg.

COSMOS 1847, 1987-46A, 18011.
Launched: 1340, 26 May 1987 from Plesetsk by A-2
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical, camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mision Military photo-reconnaissance over an extended period.
Orbit: 169 x 346 km, 89.68 min, 67.16 deg, manoeuvrable.

COSMOS 1848, 1987-47A, 18017.
Launched: 1245, 28 May 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. Overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 357 x 414 km, 92.30 min, 72.86 deg.

UK Firm to Build Fuel Plant

Air Products Limited is increasing its involvement in the European space programme with the sale of an air separation plant to the Centre National d'Etudes Spatiales to provide liquid oxygen and nitrogen for fuelling Ariane rockets. The project is worth over £5 million.

The plant will be at French Guiana, the location of the European Space Agency's launch site, where the parent company, Air Products and Chemicals, already ships liquid hydrogen as part of Ariane's launch programme.

Design for the new plant is now under way at Air Product's European headquarters at Hersham in Surrey and fabrication will take place at the company's manufacturing works at Acrefair in North Wales.

When site erection is completed, the plant will be commissioned and handed over as a customer owned and operated plant. The on-stream date is set at mid-1988.

INTERNATIONAL SPACE REPORT

Infrared Space Observatory Flies High

The European Space Agency (ESA) has decided that the Infrared Space Observatory satellite (ISO), expected to be launched in 1993, will now be placed in a 24 hour orbit rather than the 12 hour orbit originally planned, *writes Dr. John Davies.*

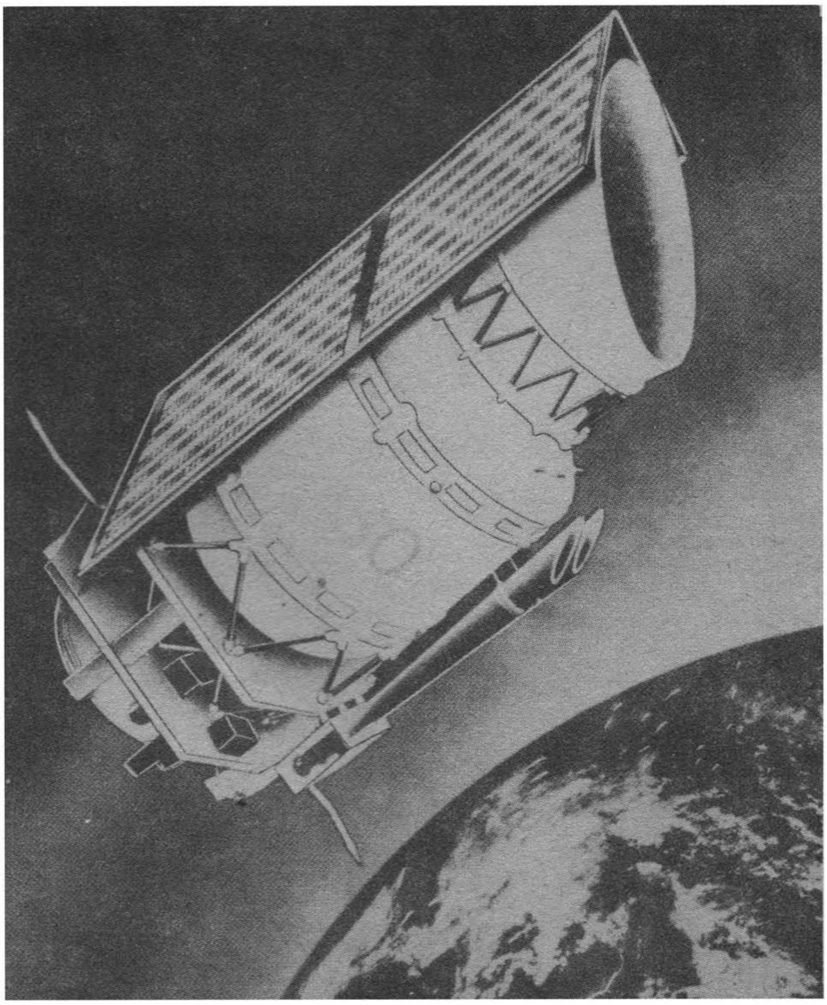
The details of the new orbit are apogee 70,000 km, perigee 1000 km and inclination five degrees. The reason for the change is that in the new orbit ISO will spend nearly 75 per cent of its time outside the Van Allen radiation belts, which means that the effects of trapped protons and electrons on the sensitive infrared detectors will be much reduced. The reduced radiation background will in turn lead to a considerable improvement in the sensitivity of the scientific instruments.

Another benefit of the higher orbit is that ISO will spend less time close to the Earth, reducing the heat input to the cooled infrared telescope. This will reduce the rate at which the vital liquid helium coolant boils away and means that the lifetime of the mission may be increased by two or three months.

The disadvantage of the 24 hour orbit is that it requires the use of a dedicated (and hence more expensive) Ariane 4 launcher instead of sharing a launch with another satellite.

To offset the extra launch costs, ESA will use only one ground station to communicate with ISO instead of the two stations originally intended. The loss of a ground station means that ISO can only be operated for about 14 hours per day and that about eight hours of usable observing time per day will be lost (the remaining time is lost anyway since the satellite is in the radiation belts).

The loss is considered acceptable because the 14 hours per day which are available offer much better observing conditions than the 20 hours per day possible in the original 12 hour orbit, and the overall result will be an improved scientific return from the mission. In the meantime ESA is seeking an international partner to provide a second ground station. If such a partner can be found, the remaining eight hours of good quality observing time may yet be saved.



This view of the ISO satellite shows the relocated solar array, but not the new position of the star trackers (the dark telescopes on the underside) which are now planned to be attached to the upper portion of the satellite. *Aerospatiale*

There have also been other changes to the proposed design resulting from the switch of launch vehicle from Ariane 2 (which was the launcher on which the original mission concept was proposed) to Ariane 4.

Most obvious is that the new design has done away with deployable solar panels in preference to placing the solar array on the satellite's Sunshield, giving ISO a close resemblence to the earlier IRAS satellite.

Platform Accident Delays Launch

NASA's last Atlas-Centaur rocket (AC-68) was damaged on July 13 at Kennedy Space Center when a service platform hit the Centaur stage's hydrogen tank, causing the tank to rupture and depressurise. There were no propellants on board.

Four General Dynamics Space Division technicians suffered minor injuries as they left the area, KSC officials said. They were treated at the scene and released.

The accident occurred as the service platform was being removed in preparation for lifting the Centaur stage to troubleshoot a liquid oxygen leak.

Launch of the Atlas Centaur, carrying Fltsatcom 8, had already been postponed to July 24 because of a liquid oxygen leak which the technicians had been investigating at the time of the accident.

Japanese Satellite Data for Australia

Images from the Japanese Marine Observation Satellite (MOS-1), launched on February 19 (*Spaceflight*, April 1987 p.139), will be received directly by a new Australian ground terminal from next year.

Under an agreement recently signed between the two countries a facility at Alice Springs will be modified for a six month series of experiments using MOS-1 data beginning in April.

At present, stations receiving MOS-1 data are operating in Japan, Thailand and Antartica. The European Space Agency also receives direct images.

INTERNATIONAL SPACE REPORT

Commercial Orders for US Delta Rockets

US Delta rockets built by McDonnell Douglas will be used to launch two satellites for British Satellite Broadcasting, a London-based consortium that plans to establish a direct satellite-to-home broadcasting system covering the UK and western Europe.

The Hughes-built satellites will be launched by commercially available versions of the Delta. The first of the satellite launches is scheduled for the third quarter of 1989, using a current model Delta. The second launch, a year later, will use the more powerful Delta II.

Inmarsat, the 48-member country cooperative that operates the satellite system used for global maritime mobile communications has signed a contract with McDonnell Douglas for the use of a Delta II to launch one of its second generation Inmarsat-2 satellites.

Inmarsat currently leases capacity on nine satellites and has placed an order for three higher capacity satellites with an international consortium led by British Aerospace. The first of these is scheduled to be ready in 1988 with a launch by Delta planned for December 1989.

"We have contracts for launches on the Shuttle but these launches will not now be available until the 1990s. We have contracts for Ariane but the scheduling of these launches is also uncertain," said Olof Lundberg, Inmarsat Director-General.

"This Delta launch will enable us to get Inmarsat-2 into orbit and in service at the earliest possible date," he added.

* * *

McDonnell Douglas has been chosen by the Government of India, Department of Space, to launch a communications satellite. The mission, scheduled for the second quarter of 1989, will be the first commercial Delta launch for McDonnell Douglas.

The satellite, called Insat ID, is the fourth in a series of Indian communications satellites and will be launched from Cape Canaveral, Florida. The first of the series, Insat IA, was launched on a Delta by NASA in 1982.

Insat ID will provide national communications, meteorological observation and television broadcast information for India. The satellite is being built by Ford Aerospace in California.

Japan Reaches for Moon and Planets

Japan's Institute of Space and Astronautical Science (ISAS) plans to launch a Lunar probe, Muses-A, in 1989 that will orbit the Moon.

Since ISAS's first satellite launch in 1970, payload capacity has been increased by simple increases of rocket length and the addition of strap-on boosters. With the planned Lunar launch, the maximum extension of present performance will be reached, and subsequent interplanetary missions will have to await the introduction of a new launch vehicle in 1993, capable of placing two tons in low-Earth orbit, i.e. about three times the present payload.

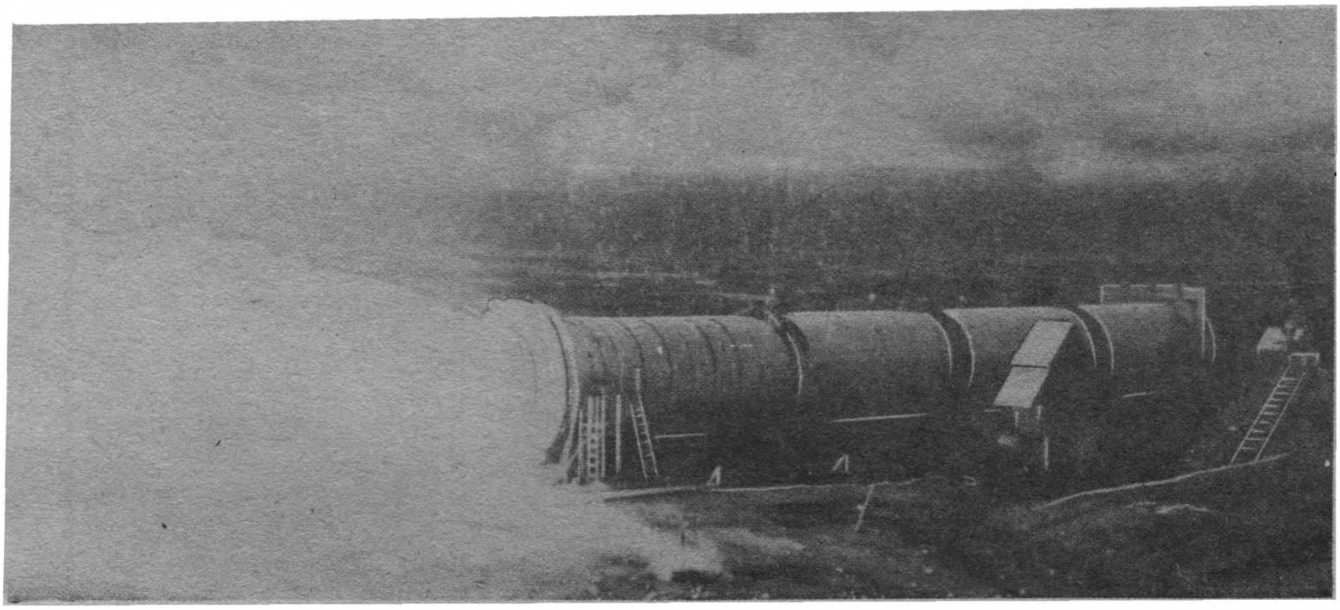
Before these plans can go ahead ISAS must first seek approval of Japan's Space Activities Commission to increase vehicle tail diameters above the 1.41 m limit imposed in 1970 as a condition for its operational independence from Japan's National Space Development Agency (NASDA). Interplanetary missions under consideration include a follow-up Lunar satellite and Venus atmosphere probe.

Space Shuttle Booster Tests Under Way

A series of full-scale solid rocket booster test firing began at Morton Thiokol's Wasatch operations site on May 27.

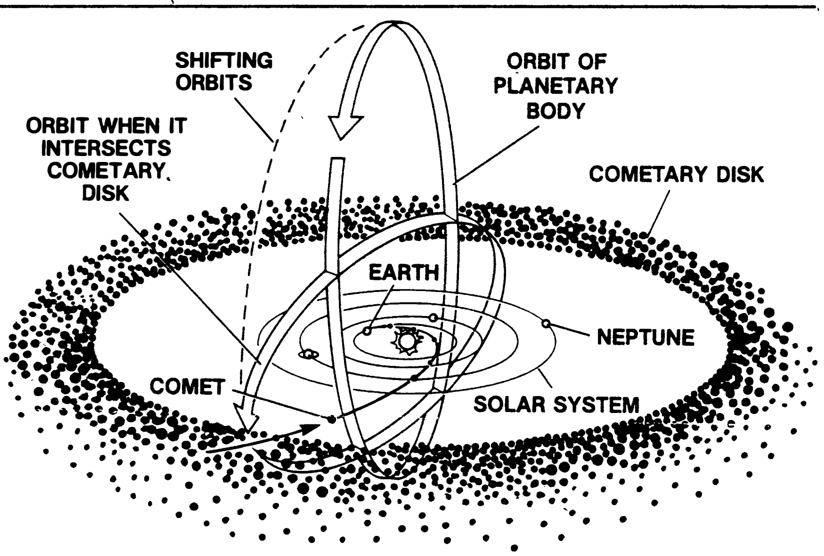
The first test (picture below) was not of the configuration to be used when Shuttle flights resume, but it provided data to help evaluate materials and engineering concepts which ultimately may be incorporated in the redesigned solid rocket booster (SRB).

The 120 second burn in a horizontal test firing was the first full duration test firing of a Shuttle SRB since May 1985. First tests of the redesigned motor were due to take place in late August.



INTERNATIONAL SPACE REPORT

Tenth Planet Mystery



The diagram shows the proposed orbital track for a tenth planet which is almost at right angles to the orbits of the other planets and intersects the cometary disk.

According to NASA scientist Dr. John Anderson, a tenth planet may exist beyond the known Solar System. If it does, it must travel in an orbit nearly at a right angle to the orbits of the known planets and be so elongated that it only nears the Sun and known planets every 700 to 1000 years.

His conclusion was first put forward in a book, "The Galaxy and the Solar System", published by the University of Arizona Press. It follows examination of long-term astronomical measurements, together with the absence of gravitational effects of a tenth planet on the Pioneer 10 and 11 spacecraft. Pioneers 10 and 11 are in the far outer solar system and represent a uniquely sensitive measuring system for gravity effects.

Astronomers have long sought a large planet or other object beyond the orbits of Neptune and Pluto. Data exist on orbits of the planets to indicate that some kind of celestial object has affected the orbits of the outer planets. Until 1978, that object was thought to be Pluto. However, Dr. James Christy, of the US Naval Observatory, found a moon around Pluto and determined that neither the planet nor its moon were massive enough to cause the long-observed waverings in the orbits of the outer planets.

Anderson believes some other object must be responsible for these phenomena. He has reviewed many types of orbit measurements taken over a period of almost two centuries. His reinterpretations of these data now appear to show that, from the present back as far as 1910, all types of measurement techniques have failed to show any unexplained outer planet variations. This despite the fact that most orbit experts had long assumed that these well-known effects were continuing into the present century. Between 1810 and 1910, during which measurement techniques were comparable to modern astronomical standards, evidence for an additional solar system body was strong.

Long time periods are required to reach final conclusions about the very small effects on planet orbits because the outer planets take a very long time to orbit the Sun. Therefore, measurements of small position drifts in orbital arcs take decades. Uranus, for example, circles the Sun once every 84 years and Neptune once every 165 years.

Anderson maintains that the best explanation for an object very likely to have been there for at least 100 years, and then disappearing is a "planet" on a greatly elongated orbit. His data also tends to strengthen the idea that some kind of tenth planetary body may have caused the cataclysmic comet impacts some scientists believe are responsible for periodic mass extinctions, including that of the dinosaurs.

The Pioneer spacecraft are good indicators of the gravitational pull of celestial objects because they generate almost no forces of their own which affect their trajectories. They are stabilised by their own spin, rather than the thrusts of control jets, and like tiny planets, they float free in the gravity fields of the solar system planets. Unexpected changes in their velocities would show the presence of an uncharted star or planetary object. Because their trajectories move them rapidly outward from the Sun and because of precise radio tracking, they are very exact gravity sensors.

In three years of precise measuring, Anderson has found no gravitational effect on Pioneers 10 and 11 which cannot be explained by the known nine planets. His review of planetary orbit data appears to show that this has been the case for the past 75 years and that the data gathered between the 17th and early 20th centuries, showing orbit irregularities, are valid. One of the current theories, which he feels fits the data quite well, is that of a planet whose orbit is tilted at almost right angles to the orbits of the other planets. In one dimension, this orbit might be from 10 to 20 billion miles across.

Dr. Anderson is principal investigator in celestial mechanics for the Pioneer spacecraft and is located at NASA's Jet Propulsion Laboratory, Pasadena, California.

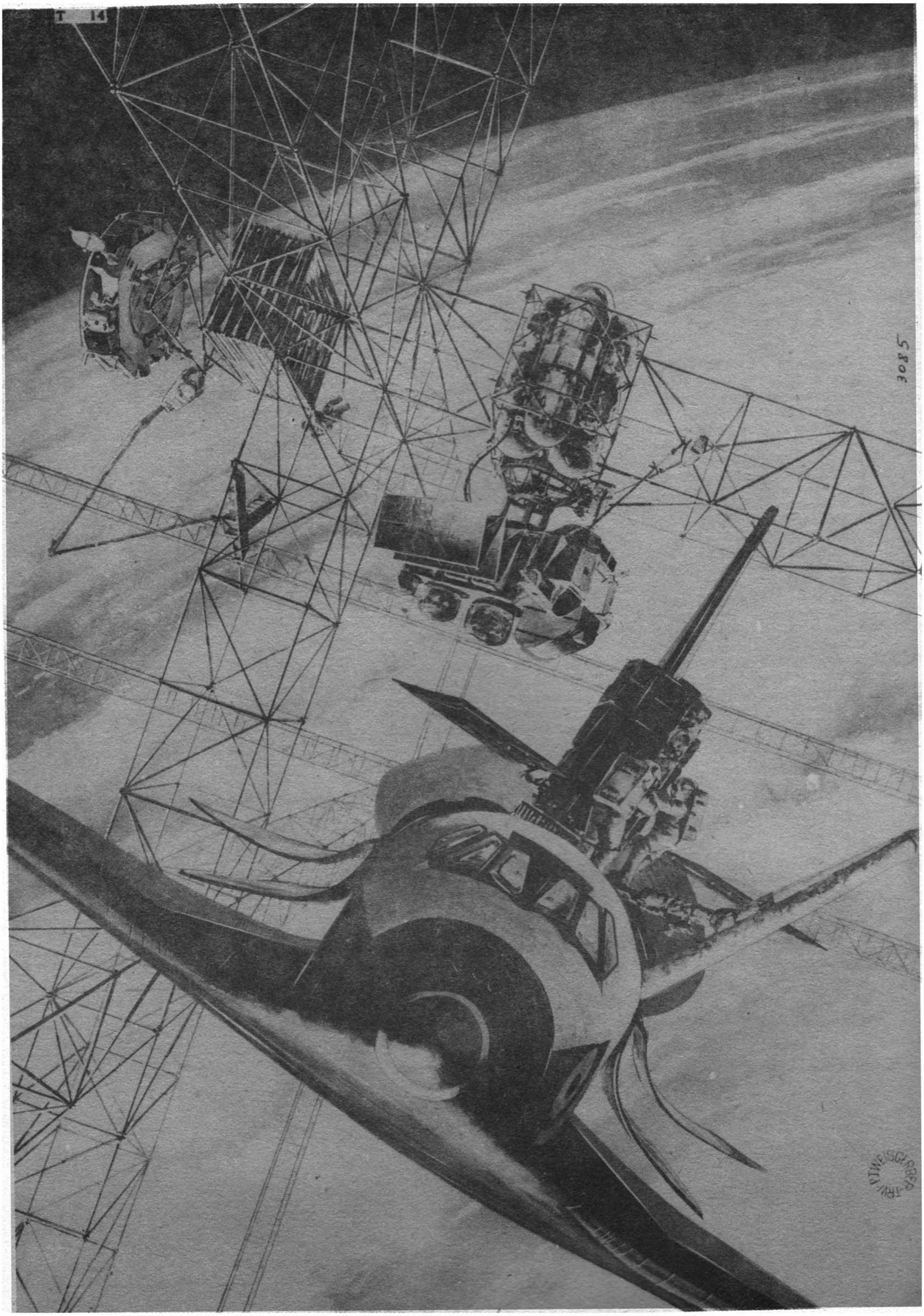
Space-based Ultraviolet Observatory

British Aerospace Space and Communications Division has been awarded a contract from the European Space Agency to lead a feasibility study into a space-based ultraviolet observatory.

Work on the contract, worth £250,000 and lasting one year, will be undertaken at the Division's Bristol site in the UK. The observatory, with a proposed launch date in the mid-1990s, will comprise an Earth orbiting spacecraft carrying a grazing incidence telescope serving a set of ultraviolet spectrographs.

The project is named 'Lyman' after the Harvard professor Theodore Lyman who pioneered investigations into the far ultraviolet spectrum. Its aim is to explore ultraviolet emissions which are invisible to the human eye and which cannot be detected from Earth due to the filtering effect of the atmosphere.

Operating in the largely unexplored lower ultraviolet regions (100-2000 Å range) the mission will provide information on the chemical composition and physical characteristics of stars, galaxies and other celestial objects.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Has Manned Space Flight a Future?

In 1986, a series of launch failures threw the West's programme of satellite launchings and manned space flight into disarray. Not so with the Soviet space programme, which now shows a 10 year lead over NASA's in the practical utilisation of space.

Questions arise and beg to be answered when plans go awry. Are East and West in a critical 'space-race', or does it not matter? Do we actually need a manned space programme? Or even a space programme at all?

Recent statements in the press have implied that manned space flight is a waste of time and money. The counter-view is presented in this article by Dr. M.H. Harrison, who takes a look at what space has to offer and argues for its manned exploration.

The Two Camps

In the United States last year the loss of the Space Shuttle Challenger was quickly followed by failures of Titan and Delta rockets, and by the cancellation of the Centaur upper-stage booster. In Europe, Ariane failed for the fourth time in 18 launches. The seriousness of such a situation for the West's space programme was indicated by *Jane's Spaceflight Directory*, which put NASA ten years behind the Soviets in the practical utilisation of space. With the benefit of hindsight it seems that the American decision taken in the 1970s to abandon expendable launch vehicles in favour of the Space Shuttle may have been mistaken. It is certainly true that for many years opponents of the manned space programme have been arguing that the Shuttle is too complicated and too expensive, and that unmanned spacecraft can perform many of the tasks which were to have been performed by the Shuttle – for example, launching satellites.

In a recent article in "Scientific American" [1], written before the loss of Challenger, James Van Allen described as a "slaughter of the innocent" 17 research programmes which had been cancelled or postponed because extra funds were needed to support the development of the Space Shuttle. So far, the Shuttle has cost the American tax payer 30 billion dollars and in the decade from 1975 the cost of launching the Shuttle rose by 80 per cent, to approximately $34,000 per kg of payload – too much for commercial ventures other than telecommmunications. An astronaut's time has been costed at $6,000 per minute!

It is hardly surprising that, in post-Challenger America, supporters of the manned space programme are having a difficult time. This beleagued group has, however, recently received some much needed support from the Presidentially-appointed "National Commission on Space". In its report entitled "Pioneering the Space frontier: Our Next 50 Years in Space" (***Spaceflight***, May 1986, p.194), the Commission has put forward ambitious, some would say visionary, proposals for restoring and maintaining America's leadership in space. These include spaceports, lunar bases and the exploration of Mars. The Commission emphasised the crucial need to reduce dramatically transport costs to low-Earth orbit and strongly endorsed NASA's planned manned space station.

Diverse manned and unmanned systems work together in this dramatic artist's impression of activity around the planned international manned space station in low-Earth orbit. *TRW*

"A human crew can make the difference between not just the success or failure of an experiment, but between the success or failure of a mission."

Equally powerful support for the manned space station has come from the Business-Higher Education forum. This independent group has published a report, "Space, America's New Competitive Frontier", which describes the Station as "the centrepiece of America's space infrastructure for the next decade". Conservative estimates put the cost at $8 billion, but this does not include running costs, which few seem prepared to talk about, and which could easily exceed $30,000 per hour. As for the proposals of the National Commission on Space, these would require between $700 and $800 billion dollars if implemented in full.

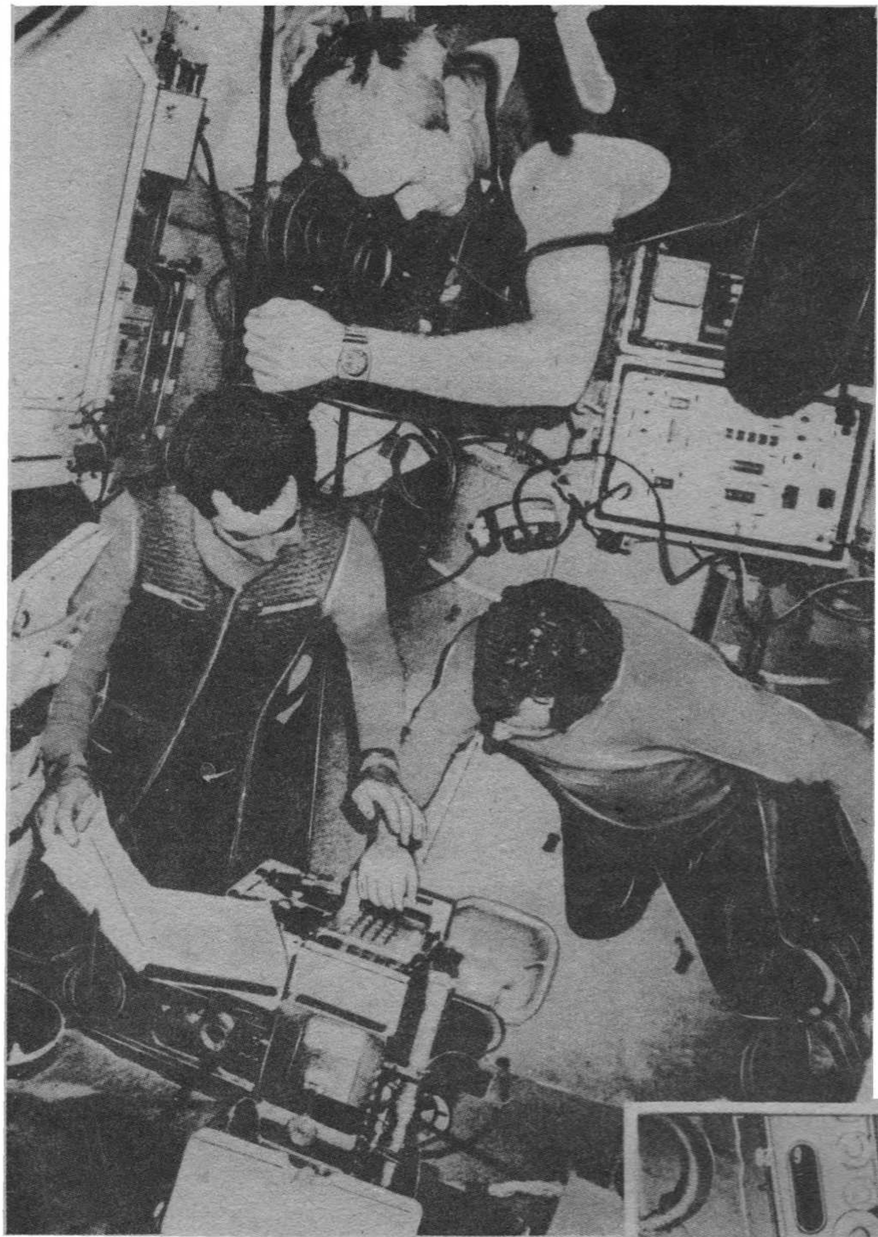
Figures such as these can make even the most ardent space enthusiast hesitate, especially when it is realised that a substantial proportion of these colossal sums arises from the declared requirement to support a human presence in space. The question that has to be asked is whether that human presence is really worth the cost involved; in those immortal words from *Star Trek*, should we "boldly go"? Or, to extend the question further, is it worth investing in space at all?

The Worth of Space

The answers to these questions depend to a great extent upon what is meant by "worth". In a strictly commercial sense, worth means receiving a profitable return on an investment. Defined in this way, the best example of space technology which has so far achieved economic viability is telecommunications. But worth may also be reasonably regarded as including social, cultural, and humanitarian benefits. In which case other more speculative, and at present non-profitable, areas of space technology, such as remote sensing and specific applications of the microgravity and vacuum environment of space, may be eminently worthy of investment. Indeed, these areas could eventually become economically viable too. Unfortunately, however, there are no guarantees that this will be so, and that is the problem.

For the two 'super powers' guarantees are unnecessary. The military implications of achieving superiority in space are such that one side cannot afford the risk of being left behind by the other – hence the emotive description in *Jane's* of the present Soviet lead as "almost frightening". Military considerations are much less important for countries like the UK, France, Germany, and Japan, and yet they too are taking both remote sensing and microgravity applications very seriously. The reasons are not hard to identify. Using remote sensing, a spacecraft can provide in a few seconds as much information about an area of the Earth's surface as 25 high-altitude aircraft. This information can have widespread applications for agriculture, forestry, geology, hydrology, and oceanography, as well as for more familiar meteorology. Remote sensing can improve land uitilisation, both rural and urban; it can locate oil, mineral, and water reserves; it can identify and follow pollution, potentially dangerous weather patterns and disease infestations of crops.

The microgravity environment of a



space vehicle can be utilised for the refinement of biological materials, leading to improved treatments for a wide variety of medical conditions; it can be utilised for the production of superior semi-conductors for use in ultra-fast computers; it can be utilised for the production of materials of superior strength, shape, structure, or with superior insulation characteristics – materials which will have applications ranging from high performance aircraft to home construction.

It might reasonably be concluded, therefore, that remote sensing and microgravity applications are technologies well worth pursuing. Unfortunately, in economic terms, these are both speculative technologies – although remote sensing less so than microgravity applications. To make matters worse, there is a very long lead time for investment. Although satellite communication systems achieved economic viability fairly rapidly, remote sensing still has to show a commercial pay-off after nearly two decades of investment. There is every reason to believe that it will take far longer than this before factories in space are producing materials which can be sold at a profit. No commercial organisation would be prepared to commit the vast sum of money needed to support a microgravity research and development programme over that length of time when there is no guarantee of a viable product at the end. Which is precisely why at present much of the financial support for microgravity research is coming not from industry but from governments. This is inevitable and essential. If it is considered to be in the national interest to support risky space technologies, then that support requires a policy of

Above left: Cosmonaut Vladimir Djan films an experiment conducted by Alexandre Ivantchenko and Frenchman Jean-Loup Chrétien on Salyut 7. Chrétien, who is due to visit Mir next year, is also pictured above.
Left: Syrian Mohammed Faris with Valdimir Titov. Faris recently visited the Soviet Mir Space Station with cosmonauts Victorenko and Alexandrov.

national investment. Without such a policy, the USA would not have a space programme at all. And Britain would not be the world's third largest manufacturer of communication satellites (after the USA and the USSR), since the UK satellite industry was born from the national satellite programme.

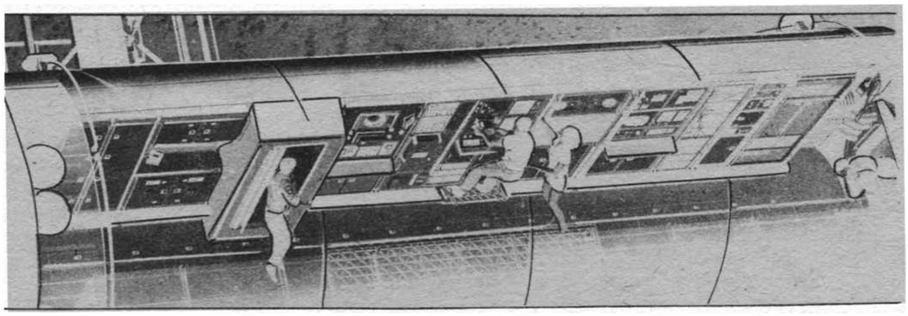
Nationally funded research and development programmes are not without their disadvantages, the worst of which is that they are highly vulnerable to changes in the political climate, and in particular to that eternal conflict between policy and the cost of implementing policy. This is especially true of support for space technology, which is so very expensive and which takes so long to produce anything useful – or even usable! Britain discovered this in 1960, and again in 1971, when national economic constraints forced the cancellation first of the Blue Streak and then of the Black Arrow launchers.

Ironically, just four years after the demise of Black Arrow, the European Space Agency was formed precisely in response to a general recognition that no European country could afford a large space programme entirely on its own. This organisation, despite the diverse political, social and technological ambitions of its members, has proved remarkably successful. Europe can now afford to invest in technologies which are perceived as 'high risk', but which might lead to that elusive commercial crock of gold.

Even with international collaboration the exploitation and exploration of space remains a very expensive business; the ESA budget for 1986 was $759 million. Put in perspective, however, this is equivalent to only 0.04 per cent of the total gross domestic product of the member countries, and compares with the 0.2 per cent committed by the United States. Nevertheless, there are some who would still argue that this money could be better spent; for example, by investing in terrestrial technologies more likely to have an immediate effect on reducing unemployment within Europe. While one may applaud this sentiment, political and economic realities make any such altruistic action highly unlikely. It should be remembered that investment in space is but a tiny fraction of investment in national defence programmes. Just as weapons of war cannot be 'disinvented', so space will not go away. Also, both space and defence are big employers of people. But the cynics might further claim that all there is to show for 30 years of investment in space are a few lumps of Moon rock, and non-stick frying pans! So why bother?

Space Benefits

Quite apart from the tremendous geological importance of what were actually hundreds of pounds of Moon rock, and ignoring the culinary bliss afforded to countless millions by cooking pots that stay clean, space has affected and changed the lives of virtually every man, woman and child on this planet. It is all too easy to forget how exciting those words "live by satellite" once were. In just three decades communication satellites have tied the world together, creating a "global village". Whether these satellites are used for conducting business, for education, or for data and information transfer, mankind benefits.



Impression of how a Space Station laboratory module may look. The astronaut to the left is working in a commercial processing area, the two astronauts in the centre are at a general work station and a fourth astronaut (far right) enters the laboratory from a tunnel connecting it to another module and the Space Shuttle. *Boeing*

International telephone, telex and television are now a part of our lives that we easily take for granted, and yet they each depend to a great extent on communication satellites. Letters and documents can be 'sent' over thousands of miles in less than two minutes. Instant communication means instant information. From medicine to politics, and from big business to entertainment, that means a safer, happier, and more prosperous world. And while optical-fibre cables may soon rival satellites in some areas of communication, in others such as point to multipoint links, data services, and mobile communications, satellites will remain pre-eminent.

Travel is made safer because of satellites, with the near-reality of point navigation anywhere on Earth's surface to an accuracy measurable not in kilometres, but in metres. Travel is also made safer because of the meteorological satellites which can track and monitor severe weather conditions, and the communication satellites which permit shipping and aircraft to be quickly notified of danger, and routed elsewhere. Already, many thousands of lives have been saved as a result of timely warnings, provided by orbiting weather satellites, of hurricanes, floods, and other natural disasters.

Neither can the scientific satellites and unmanned planetary probes, dedicated to seemingly abstruse and exotic studies, be discounted from the sum total of benefits accruing from investment in space. In 30 years these spacecraft have provided more knowledge about the Universe than had been obtained in the preceding three centuries. This knowledge may seem to be of little practical use - yet. But it is proving to be of inestimable scientific, and indeed philosophical, significance. For it impinges upon the most fundamental questions of our existence: how did we get here?; where did we come from?; are we alone? Nor should it be forgotton that it is the gradual, slow accretion of knowledge that suddenly leads to technological breakthroughs which can benefit mankind. The search for knowledge can itself be regarded as a justification for going into space.

No matter how apparently persuasive the argument, the opponents of space exploration will probably remain convinced that it is all a waste of time and money. But a comment made by Max Planck in his "Scientific Autobiography" is particularly pertinent: "A new scientific truth does not triumph by convincing its opponents and making them see a new light, but rather, because its opponents eventually die, a new generation grows up that is familar with it."

Adults now approaching middle age were at school when the first satellites were launched; adults in their twenties were young children when Neil Armstrong first set foot on the surface of the Moon. To them 'space' is a fact of life. The Challenger tragedy has shown, however, that the human occupancy of space should not be taken for granted. Furthermore, even some of the most powerful proponents of space exploration point out that most of the benefits from space investment have came from the unmanned sector of the space programme - from communication satellites, meteorological satellites, and other remote sensing satellites. Is it really necessary, then, for human beings 'to boldly go'?

The Human Presence

Because the unmanned space programme has so far proved to be more economically productive than the manned space programme, it does not necessaily follow that this will remain the position in the future. Just as there are now those who foresee no useful purpose for man in space, a little over 30 years ago there were those who foresaw no practical use for artifical satellites. Present opposition to man in space is centred around the proposed space station, which, according to James Van Allen, "... will seriously

diminish the opportunities for advancing space science and technology if it proceeds as planned" [1]. He goes on to claim that "most national goals in space are better realised by robot spacecraft". Within the terms of his definition of "space science and technology", Van Allen is probably correct; to quote him again: "The substance of space is best thought of as a .... mixture of the traditional disciplines of astronomy, geology, geophysics, and oceanography." [1]

These are all disciplines for which objectives can usually be better achieved by machines than by human beings. But what about those other traditional scientific disciplines - chemistry, physics, and biology? In the same way that astronomy has benefited from observations made from beyond the Earth's atmosphere, so these basic sciences can benefit from the unique environment provided by a spacecraft - the virtual absence of gravity, the vacuum, the extremes of temperature, and even the radiation. Of these, the absence of gravity is potentially (and commercially) the most important. All physical and biological processes are influenced, to a greater or lesser extent, by gravity. Knowledge of what happens to these processes when gravity is absent could have far-reaching implications and applications. This knowledge can only be gained be research - research that has to be carried out by humans in space.

James Van Allen is unconvinced by the potential applications of microgravity. He refers to a study by the American National Research Council (NRC) which showed that prospects for commercially viable products have "no convincing foundation commensurate with the costs of space flight", and that microgravity research has so far yielded only meagre results. Both of the NRC's claims are true. What is also true is that the current state of microgravity applications is comparable to that of telecommunictions 30 years ago, and of remote sensing 15 years ago. Thirty years from now it is reasonable to predict that the costs of space flight will be lower than at present. Only meagre results have been obtained because only meagre facilities have been available. The Space Shuttle is an inadequate vehicle for evaluating the potential commercial applications of microgravity. Flight, and therefore experiment times are too short; the microgravity environment is unstable; and the stresses of re-entry highly disruptive. the technological value and commercial utility of microgravity will only be determined by rigorous studies following traditional scientific principles of research and development. Certainly the overly-complex, one-off experiments that have typified the approach to microgravity so far may do more harm than good; the chances of failure are high, and failure merely proves the sceptics right! It is entirely possible that microgravity will not revolutionise materials processing and will not lead, in the words of President Reagan, to "medical breakthroughs beyond anything we have dreamed possible" [2]. It is equally possible that it will. But without a human presence in space we shall never know. The enthusiasm with which the Soviets are pursuing their manned space programme suggests that perhaps they do know!

"The search for knowledge can itself be regarded as a justification for going into space."

The original conception of the space station as a "hands on laboratory, primarily in materials and life sciences" [3], seems to have become somewhat blurred of late. Nevertheless, the fact remains that it is science, and basic science at that, which stands to gain most from a manned space station. However, scientific research is not the only justification for having a human presence in space. As has been repeatedly demonstrated during Apollo, Skylab, and more recently Shuttle missions, a human crew can make the difference between not just the success or failure of an experiment, but between the success or failure of a mission.

The last minute change to the Apollo 11 lunar touchdown site, the saving of the Skylab space station, and the repair of the "Solar Max" satellite during Shuttle mission 41C are just three of many examples. Humans can respond to unforeseen emergencies and perform contingency activities; they can deploy, operate, repair and improve equipment; they can monitor in real time and take advantage of unexpected opportunities for research and measurement. Humans are adaptable, versatile, and flexible. They can improvise and evaluate. But they also exhibit one fundamental disadvantage; to do all of these things they have to be protected against an environment that is overwhelmingly hostile. Which is why the manned space programme is so expensive. Protection is required against the vacuum, temperature extremes, and radiation hazards of space. Survival depends upon the precise regulation within the spacecraft of environment parameters such as oxygen, carbon dioxide and water vapour. Food has to be provided, and human waste products removed. The absence of gravity leads to a progressive atrophy of skeletal, and perhaps heart muscle, while bones become brittle from loss of calcium.

Machines exhibit none of these disadvantages. There is no doubt that of a machine and a man performing the same task in space, the machine is by far the most cost effective. Herein lies the greatest strength of the 'unmanned lobby'. For in general, the value of man has been consistently exaggerated, while the utility of machines has been underrated. The Apollo programme is a good example – a robot craft could have brought rocks back from the Moon, albeit not so selectively and only from the surface. The Shuttle is another example. As the Rogers' Commission has observed, the Shuttle was built as a vehicle to serve many roles, and as such it became excessively complex, expensive and technically demanding to operate. It is so expensive that unsubsidised payload costs probably exceed equivalent costs for a non-recoverable launcher like Ariane. For launching satellites, arguably the most important aspect of the entire space programme at the present time, the Shuttle is an expensive luxury. The Shuttle should be used just for those jobs for which a human presence is essential.

It is certain that with future advances in the fields of robotics and artifical intelligence many tasks presently envisaged for astronauts will either become greatly modified, or will disappear altogether. For example, some types of construction work will be greatly facilitated by the development of telepresence, in which a remote operator performs normal human functions guided by sensory feedback from the work site. However, despite extravagant claims to the contrary, robotics and artificial intelligence are still at a very early stage of development. It is difficult to imagine machines performing anything other than the most simple and basic of tasks for many years to come.

Of course, both the proponents and the opponents of the manned space programme raise valid points. Common sense will almost certainly prevail; space will be explored, and exploited, by humans and machines working together. While the Space Shuttle may represent an expensive overstatement of the need for a human presence in space, it has also shown that there is a need. In the final analysis, however, it will not be rational argument that wins the day. Man in space is not a means to an end, but an end in itself. Man will go into space because, in American parlance, it is a new frontier waiting to be tamed. If the ability to tame this frontier has come to epitomise national virility and technological superiority the challenge is no different, and arguably no more dangerous, than that which has excited all explorers from ancient times to the present day. The reasons are the same too: a search for knowledge; a need for new resources; possibility of commercial opportunities; and curiosity.

Acknowledgements

Thanks are due to Mrs K H Rose and Mrs J.D Fox for preparation of the manuscript.

The views and opinions expressed in this article are those of the author, and should not be construed as representing the views, opinions, or policy of any Department or Ministry of the British Government.

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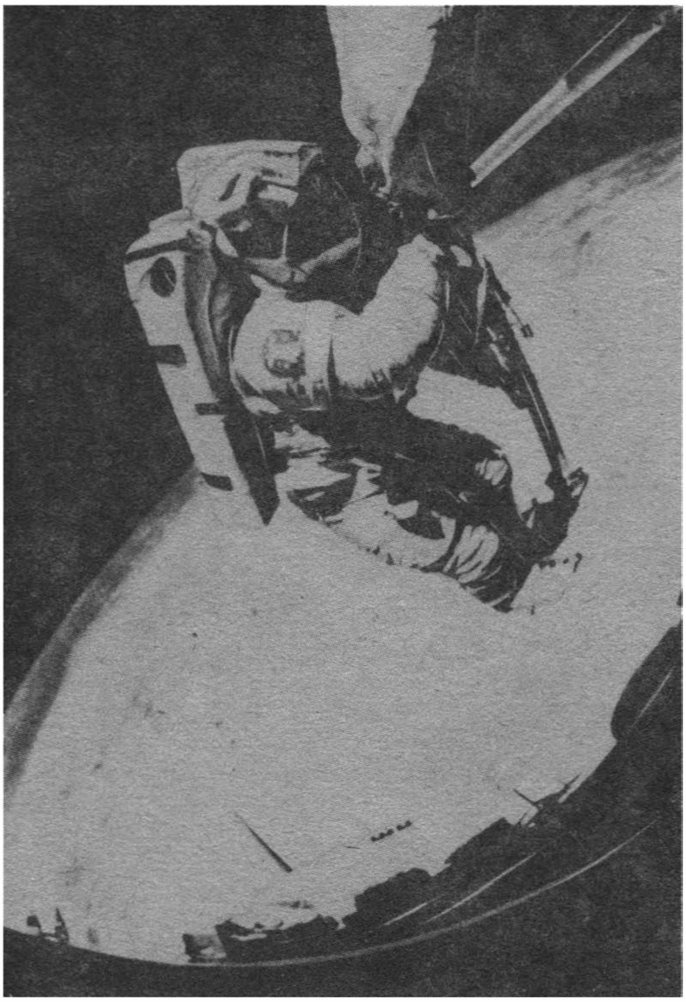
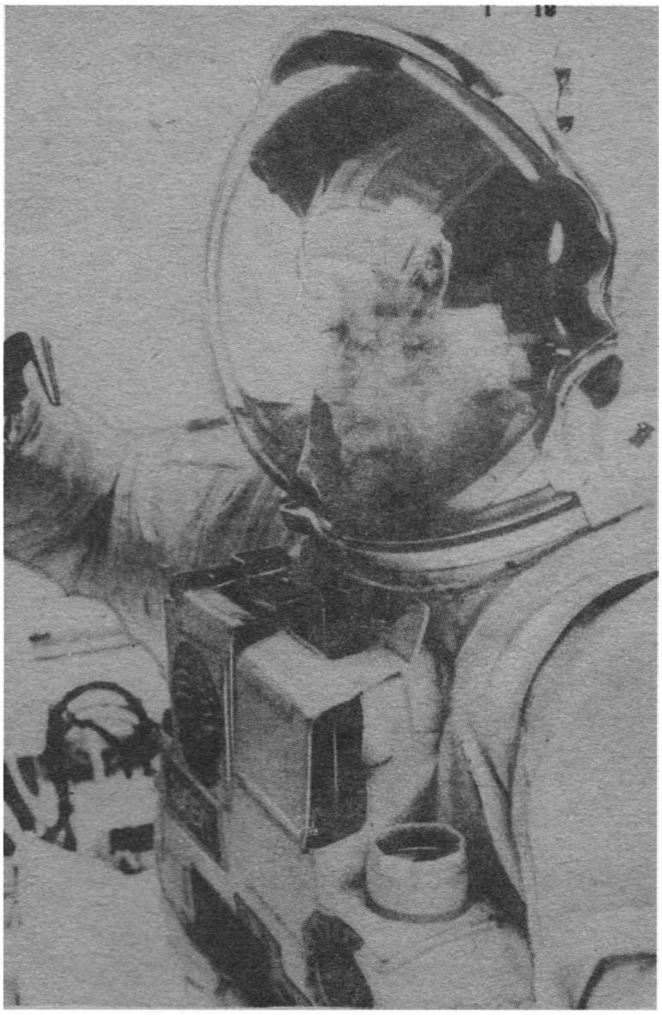




FROM A DIFFERENT PERSPECTIVE
– Astronaut 35 mm EVA Photography

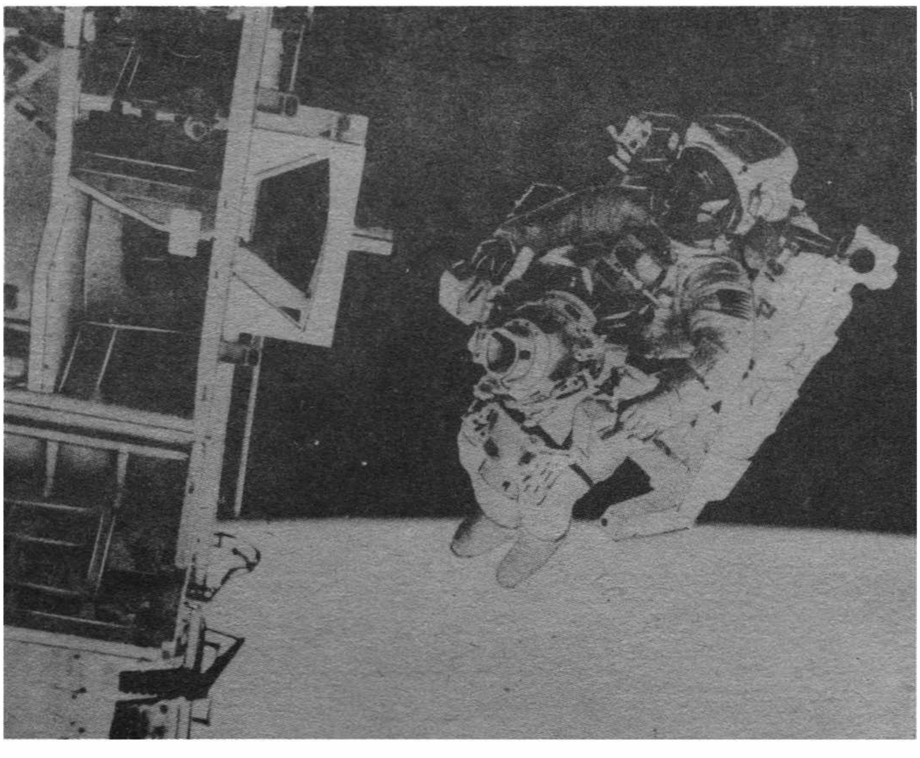
a photo essay by Joel W. Powell

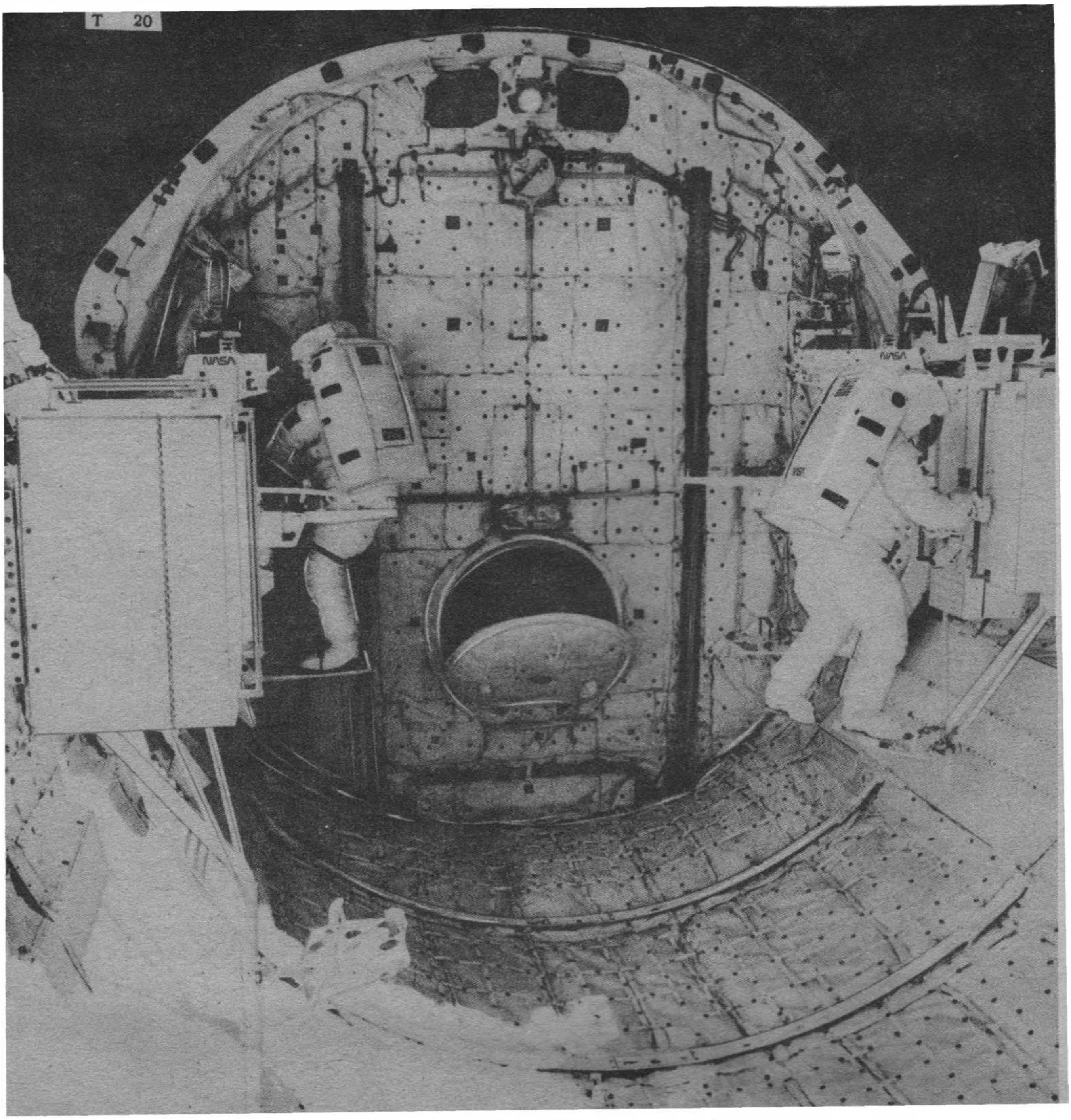
On each Space Shuttle EVA (except for the unplanned excursion on 51D) US spacewalkers have taken along a 35 mm Nikon camera to document their assigned activities. As evidenced in the accompanying photographs, the pictures offer a unique glimpse into the EVA experience from the perspective of the participant.

Above: The curve of the Earth's surface and the black of space provide an exotic backdrop for the first service call in space, the repair of the Solar Maximum satellite in April 1984. Astronaut van Hoften operates a specially built power tool to remove the faulty attitude control module while supported by the Canadarm.

Above right: The face of David Leestma is clearly outlined against the distant Earth through his tinted helmet visor in this fine study of a spacewalking astronaut by partner Kathy Sullivan. The duo were operating an orbital refuelling experiment located at the far end of Challenger's payload bay, October 1984.

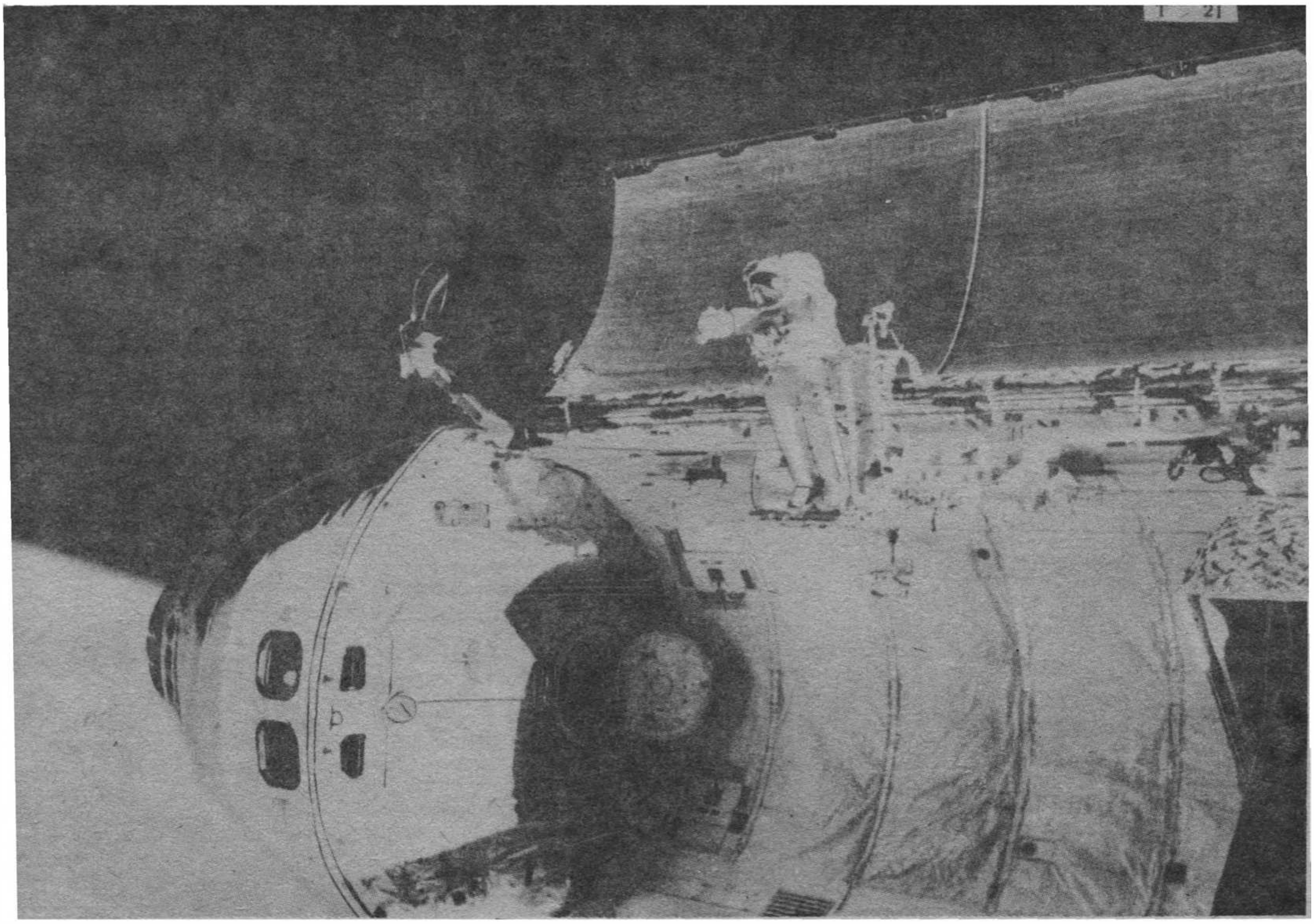
Right: Robert Stewart took this evocative picture of Bruce McCandless flying the MMU during the second 41B EVA in early 1984. McCandless is practising the trunnion pin capture manoeuvre with the attached T-Pad device for the planned Solar Max repair mission.



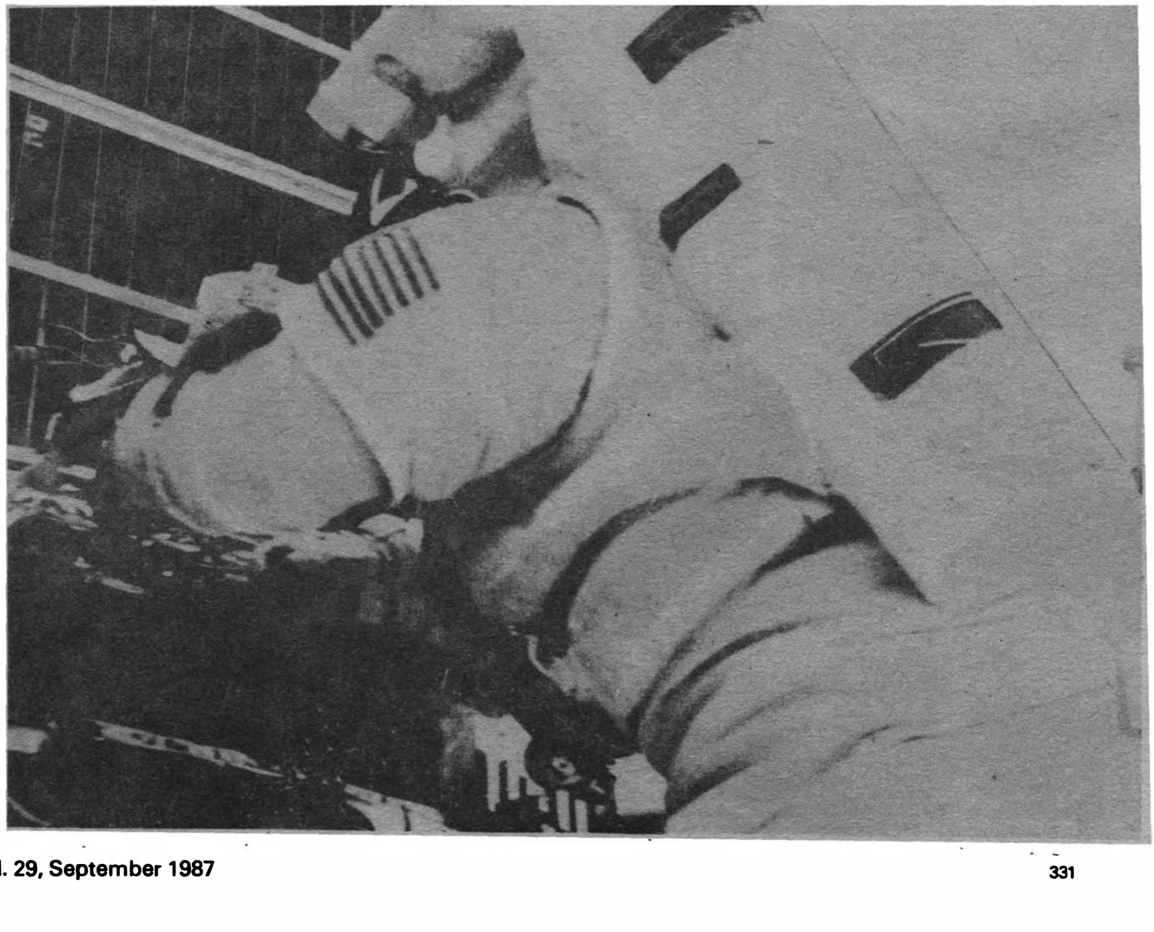


Above: With two EVA crewmen visible, who took the picture? An automatic camera aboard the captive SPAS platform in the payload bay exposed this scene during the first EVA on mission 41B. Bruce McCandless (left) prepares to don the Manned Manoeuvring Unit (MMU) as Robert Stewart (right) stands by. The starkness of the scene reflects the harsh lighting conditions of open space.

Left: Astronaut Dale Gardner celebrates the recovery of two errant satellites in this marvellously detailed photograph by Joe Allen (mirrored in Gardner's sun visor) who was supported by the Canadarm. Ironically, the two satellites retrieved in November 1984 by the orbiter Discovery could be re-launched in the near future with Chinese expendable launch vehicles.

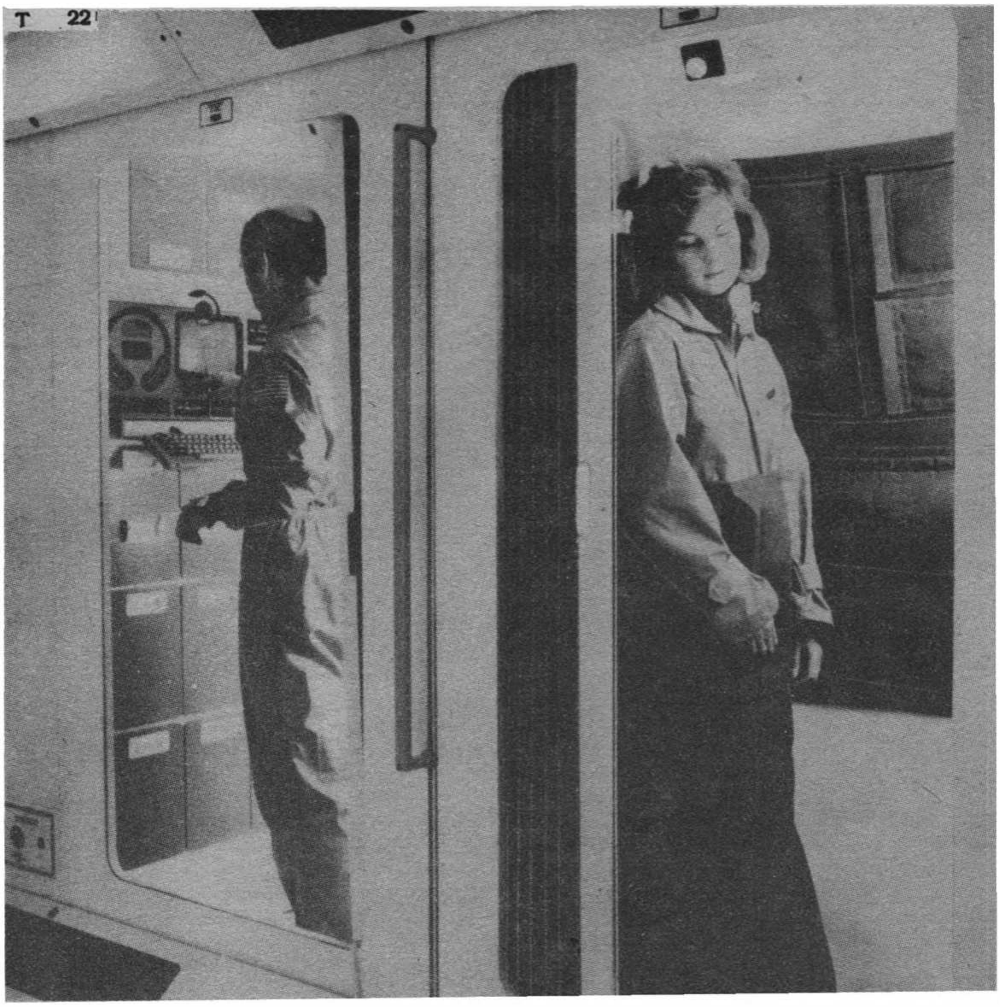


Above: From the manipulator foot restraint at the end of the Canadarm, James van Hoften snapped this picture of his partner William Fisher during the second of two satellite repair EVA's during mission 51I in September 1985. According to US astronaut Joe Allen the cherry-picker position on the Canadarm is a precarious one – he had the distinct impression that he would fall should the foot restraints fail. The sensation of motion was also enhanced when riding the arm. Watching the Earth roll by beneath the orbiter was not unlike watching the scenery from a train while riding on the front end of the locomotive.



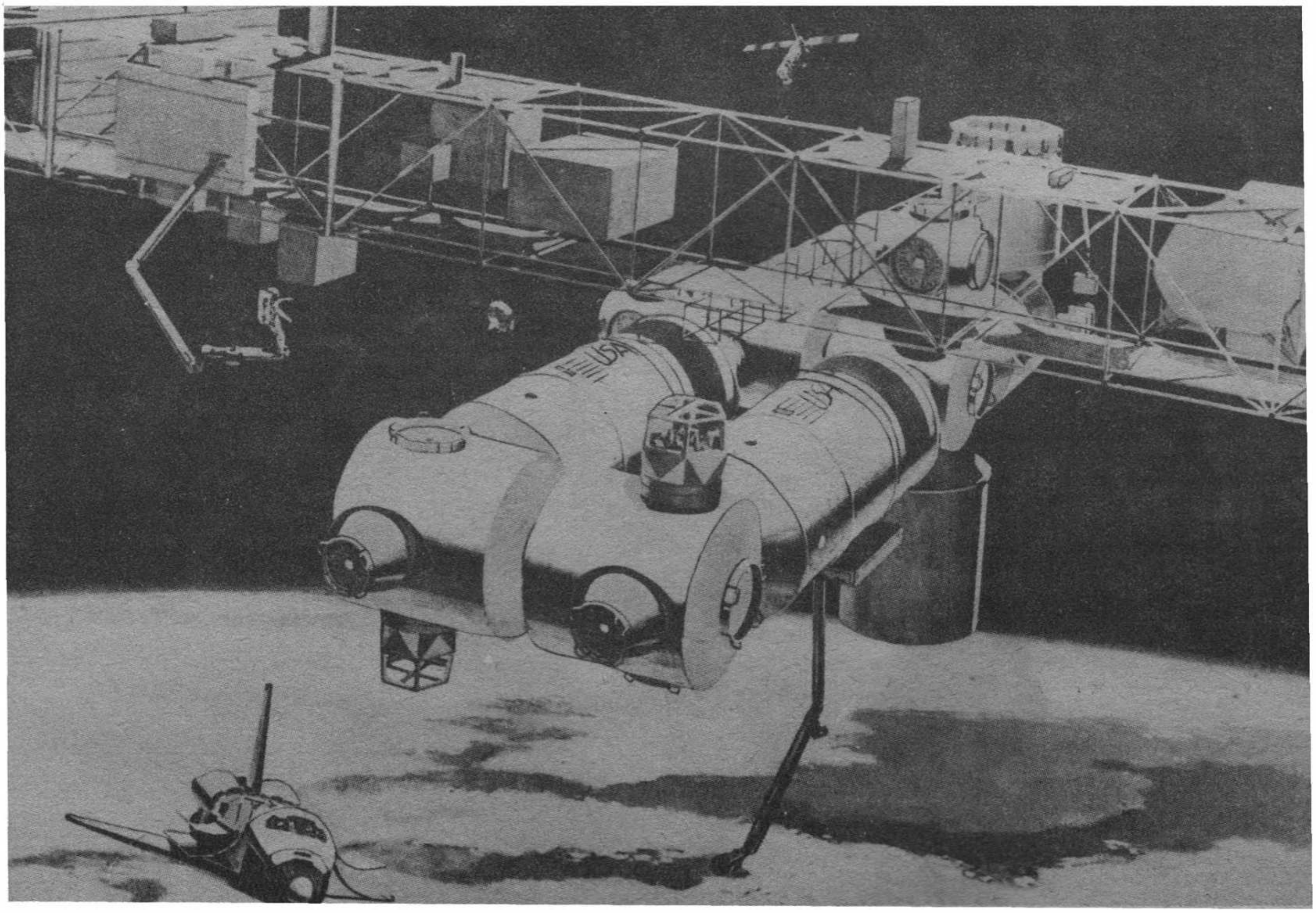
Right: Against the background of the Earth, James van Hoften works to remove the failed attitude control module of Solar Max. The rejuvenated spacecraft still functions perfectly more than three years later.

Photo credits: *NASA/Space Information Canada.*



Sleeping while standing would be uncomfortable for Boeing technician Dana Thomas but there is no up or down in space. Aboard the International Space Station, weightlessness will be a way of life for the astronauts living and working in the laboratory and habitation modules. Seen behind Thomas in this full-scale mockup of the crew quarters is her personal effects bag. To the left, Boeing engineer Phil Hedges works at the terminal in his privacy area. Storage compartments are seen above and below the computer, and a stereo headset is seen to its right.
Boeing Aerospace

This artist concept of the permanently manned Space Station (below) focuses on the pressurised modules where crews will work and live. Resource nodes connect the laboratory and habitation modules together. Two crewmen inside the cupola atop the right-hand resource node control the Canadian provided Space Station co-orbiting platform which flies in tandem with the manned base. An orbital manoeuvring vehicle is shown flying out toward the platform where it will rendezvous, attach itself and bring the platform back to the manned base for servicing. At the bottom of the photo, a Space Shuttle Orbiter prepares to dock with the manned base.



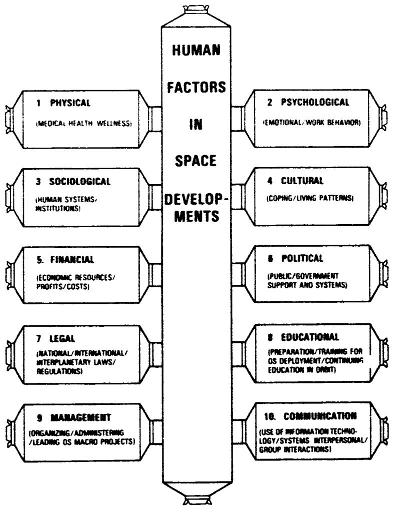
Manned Space Flight

Space Culture in the Making

Dr. Philip R. Harris, co-investigator of the Living-Systems Project, California Space Institute, writes about research now underway that will help to shape space culture in the 21st century.

Manned missions are expected to be of increasingly long duration in the coming years. Already the first permanent space station is in operation and cosmonauts Yuri Romanenko and Alex. Alexandrov are on schedule to achieve a record-breaking flight duration when they return to Earth at the end of the year. The setting up of a lunar outpost or Mars base will further extend manned missions to several years duration. In time, larger numbers of more diverse people will be living in space. Inevitably, the human factors that dominate our Earth-bound society and culture will arise in space. Fig. 1 identifies 10 areas where issues can be expected to contribute to 'Human Factors in Space Developments' and where research is needed to pave the way for the long-term future of space exploration.

Fig. 1. Human factors in space development.

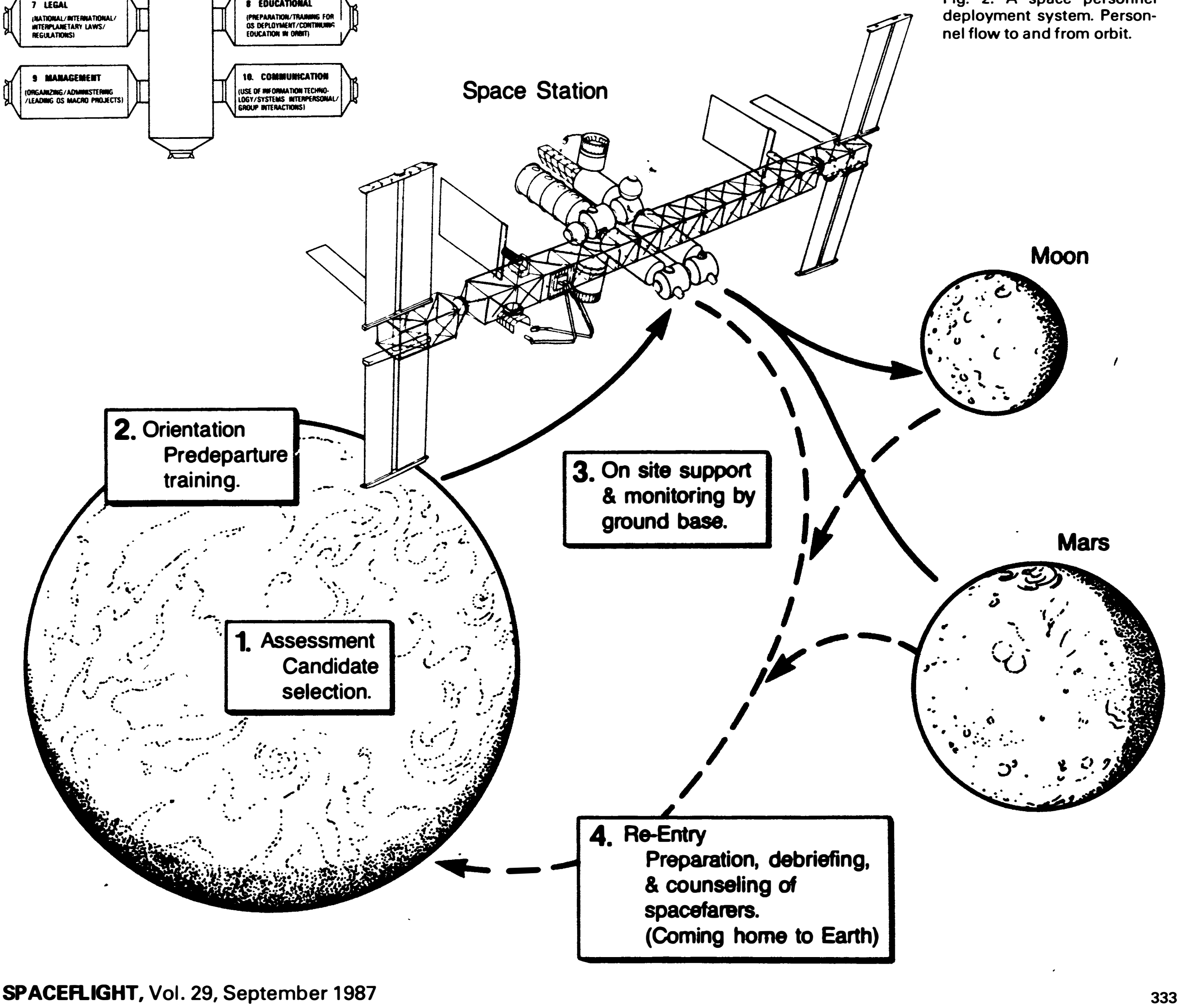


The Living Systems Project at the California Space Institute (Cal Space) is now addressing the issues of Fig. 1. It is analysing the impact of living aloft [2] upon human culture in general and the creation of a space-based culture in particular [3]. A start has been made based on experiences and evidence from current activities, both in Space and on Earth. For example, the reaction of individuals living in and returning from outer space (termed culture shock [4]) may be studied and alleviated by knowledge gained from psychological reactions and findings relative to living in remote, alien and hostile environments as well as from the limited space flights to date.

To limit culture shock, a system of preparation and support for space personnel is being designed called SPDS (Space Personnel Development System). Fig. 2 illustrates a scheme developed by the writer which encompasses four phases:

1. Assessment, including recruitment and selection of candidates for space assignments.
2. Orientation for life beyond this

Fig. 2. A space personnel deployment system. Personnel flow to and from orbit.



Space Station astronauts orbiting Earth 200-300 miles away from the nearest physician will have to rely on a clinic, such as the one in this Lockheed concept, for diagnosis and care until a Space Shuttle 'ambulance' can return them to Earth.

A Lockheed Missiles & Space Company biomedical engineer uses a full-scale mockup of a Health Maintenance Facility in Sunnyvale, California, to study the layout and 'fit'. The main goals for the facility are to monitor the health of the astronauts; to treat injured and ill crew members successfully; and to minimise the effects of astronaut physiological deconditioning as a result of 90 days of exposure to microgravity.

The facility will be required to provide 'critical care' for one crewmember for up to several weeks before transport to Earth. When none of the six crewmembers is ill or injured, the facility would continue to provide routine monitoring and exercise for the entire crew. *Lockheed*

planet, both technical and cross-cultural learning.

3. On-site support services and monitoring of personnel.
4. Re-entry policy and programme to facilitate return to living back on Earth.

In the course of this work, the following strategies are proposed for the design of SPDS:

- A survey of astronauts who have actually lived in space, albeit for very short times, to forecast future trends and needs based upon that limited experience of the relatively few "experts" alive.
- A review of literature and findings on terrestrial living in exotic environments, such as is involved in foreign relocation, offshore rigs, nuclear submarines and polar regions, particularly the Antarctic.
- An extensive compilation of research data and insights relative to extraterrestrial habitation, including Soviet Space Station analogs.
- The development of a system for the organisation of project data, and to identify possible improvements in the functioning of both living and mechanical systems on the Space Station.

With an expanding human presence in space, the next 25 years affords unique opportunities for investigations and data-base collection on such dimensions of space culture as sense of self or identity in outer space; adaptations in communication and language, dress and appearance, food and feeding habits, time and time consciousness, relationships and family, values and norms, customs and traditions, mental processes and learning, work habits and practices.

To prepare now for improved performance by larger numbers of more diverse people living for longer periods of time in space, the Cal Space investigations, under the leadership of Dr. James Grier Miller, are focusing on experiments related to the Space Station, which are seen as a prototype for future extraterrestrial settlements. This research on space habitation originated as part of a NASA sponsored summer study in 1984 at Cal Space which coordinates all space research for the University of California [5].

Before mass migration of humans in orbit, the planned international space station to be constructed by NASA is an ideal laboratory for study of space habitation and deployment issues. Apart from the astronauts themselves, the space voyagers there will include a variety of mission specialists, contract workers or technicians and VIPs. Who will or should go aloft to the station (male and female, civilian and military, Americans and other nationals/cultures, technical and non-technical types, etc.)? How will they be supported to ensure survival and quality of space life (physically, psychologically, socially and financially)? What guidance and assistance will be provided to these space travellers and their families, not only prior to launch and while in orbit, but prior to re-entry and after returning to Earth? Research into such questions has long term implications for the furtherance of cooperation among space dwellers and inhabitants of the home planet [6]. By studying space deployment issues now, humankind can prepare more intelligently for the time when permanent human communities are established elsewhere in the Solar System.

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CORRESPONDENCE

Space Plan Humiliation

Sir, I am sure I echo the feelings of most of the space community in rushing to pay tribute to the valiant efforts of Mr. Roy Gibson and Sir Geoffrey Pattie, MP, in promoting an exciting, yet realistic, future for space developments in Britain.

It is all the more appalling that, after nearly two years of diligent work, and after studying the space plan for over one year, the Prime Minister has elected to veto any increase in UK space expenditure.

Apart from the danger of accelerating the "brian drain" and ensuring (as usual!) that a pioneering concept like Hotol is likely to be built by some other country without our involvement, we have shown to our ESA partners that this country is not to be taken seriously in any collaborative project which might take time or cost money. Thus our "stock" as a European partner is likely to suffer dramatically.

At a time when cosmonautics is increasingly becoming an arm of Soviet diplomatic and foreign policy as well as an economic and industrial matter, this country faces the further humiliation of establishing a National Space Centre and an Institute of Space Biomedicine for collaboration with the USA and USSR, and then refusing to provide funds for even a half-way reasonable space programme.

Increasingly, matters of foreign and diplomatic policy are going to involve astronautics through intelligence and resource data gathering, communications and perhaps energy production or even waste disposal and peace keeping. Regrettably perhaps in world affairs, to have a voice in the councils of nations, you must have a visible presence and expertise. The country's interests and opinions (for example, in future ESA launches, etc) will therefore count for less – not so much on merit but because as the French will say, we are not "hommes serieux".

As to the long-term need for humanity to expand into the frontier of space and evolve away from the increasingly precarious habitat on one planet, I am sure that I am not alone in deploring the denial of opportunity to the youth of this country to participate in this great adventure; as the home of so many nautical pioneers and discoverers, England will have sunk low indeed.

It is a shameful decision based on short-term and largely false expendiency, and I hope that this Society will say so loudly and clearly. We should not leave it to history!

Dr. MICHAEL MARTIN-SMITH
Hull, England

The Mills Observatory

Sir, Thank you for printing Stephen Ashworth's inspiring letter on the significance of the Apollo missions (***Spaceflight***, August 1987 p.298). It rekindled in me the sense of excitement I felt back in the 1960's, which had somehow faded away over the past years.

Incidentally, Stephen Ashworth refers to Thomas Dick's book *The Solar System,* a copy of which was donated to the BIS by Peter Mills (***Spaceflight***, June 1987, p.252). Dick was a native of Dundee and stated among his many writings that every city should have public parks, public libraries and a public observatory. A young co-religionist of Dick's called John Mills (any relation?) took this to heart; when Mills died in 1889, he left his fortune to the city to build a public observatory.

Nowadays over 15,000 people a year visit the Mills Observatory to witness – in the words of its dedication – "the wonder and beauty of the works of God in Creation". Even if few of them believe in a conventional Creator-God, they still feel that sense of awe and delight – which is surely what will send future generations of humanity out into the Universe to experience that "wonder and beauty" for themselves.

Dr. FIONA VINCENT
Mills Observatory, Dundee

Space Rationale

Sir, While largely agreeing with Stephen Ashworth's long letter on the historical significance of Apollo, I would like to add another adverb to his statement "To grow means to expand – geographically, technologically and culturally". I would suggest that one ought to add "spiritually" despite Mr. Ashworth's statement that "in general space-age man does not seriously believe in a benevolent Creator-god".

At present mankind is totally unfit to be poking its nose into other people's business in other solar systems – but that is what we should be aiming for, eventually. To make ourselves fit for such a venture we need, amongst other things, humility, which has been sadly lacking of late – hence Challenger, Chernobyl, etc. The Greeks had a word for it – hubris (overweening pride) which, they said (speaking no doubt from experience!) led to disaster.

We have to learn to see ourselves as an integral part of the Universe, relatively insignificant, yet with a responsibility to treat with care that over which we have power. It is an attitude that is pretty close to being religious, in the best sense, owing nothing to beliefs. Newton, at least, had the humility to realise that he was a mere dabbler in the vastness. Modern scientists would do well to cultivate the same attitude. The best reason of all for launching out into space is neither political nor economic. It is "because it is there".

JOHN ALLISON
West Midlands, UK

Space Photography

Sir, The article "Man's Role in Space Exploration and Exploitation" by Jospeh P. Loftus (***Spaceflight***, June 1987, p.240) was most interesting. Mr. Loftus effectively shows the issues which must be considered for future manned space exploration.

In the article there is a beautiful photograph of the Space Shuttle Challenger taken a distance from the vehicle. The caption identifies it as a photograph taken by an "astronaut using the Manned Manoeuvring Unit", but as pointed out in previous correspondence (***Spaceflight***, August 1987, p.300) it was taken by a remotely controlled Swedish Hasselblad camera aboard the German SPAS-01 shuttle pallet satellite (manufactured by Messerschmitt-Boelkow-Blohm). This satellite was released from the STS-7 payload bay and later retrieved for practice in deploying and capturing satellites using the Canadian Remote Manipulator System arm (note that the arm is positioned to form a "7", for STS-7). The camera was similar to those used by the Apollo astronauts, commercially designated the Hasselblad 500EL Data Camera. The camera mounts a Reseau plate for photogrammetric use, shown as the cross marks in the photograph.

The photograph of astronaut Sherwood Spring assembling the ACCESS truss tower during Shuttle flight 61B was unfortunately mislabeled. It demonstrates very well the capabilities of man in the assembly of future space structures.

On the subject of Apollo photography, reader C.G. Legge questioned the technique used to photograph Neil Armstrong on the lunar surface obtaining the contingency lunar samples. This photograph was made by a 16mm sequence camera mounted in the right-hand window of the Lunar Module. This filmed sequence, as well as other sequences showing both Armstrong and Buzz Aldrin on the Moon, can be seen in NASA movies of the Apollo 11 flight. Photographs made with the Hasselblad equipment are noticeably sharper in appearance because of the larger format used (70mm).

I really enjoy reading your magazine and look forward to the future issues.

JOHN FONGHEISER
California, USA

CORRESPONDENCE

Number of People in Orbit

Sir, On July 22, 1987, following their launch in the Soyuz TM-3 spacecraft from the Soviet Union, cosmonauts Victorenko and Faris became the 200th and 201st humans, respectively, to reach Earth orbit (or beyond). The Soviet Union is also holder of the "100th Orbital Person" title earned by Savinykh on March 12, 1981, orbiting in Soyuz T-4 (as well as, of course, of the 1st manned orbit title for Gagarin on April 12, 1961 inside the Vostok 1 spacecraft). The US holds the title of the 100th flight to orbit executed on the Discovery Space Shuttle, which was the STS-15 launch on January 24, 1985. The US is the sole holder at present of all manned lunar titles and records.

Twenty years have passed since Gagarin's flight till the 100th person orbited the planet, but only 6 more years were required to send up the second group of a hundred human beings. A significant contribution to this space "rush" was the roomy quarters of the four US Shuttles, carrying up to 8 astronauts on a single mission. Alas, this contribution has been tragically truncated by the Challenger accident.

This count of rookies is somewhat misleading because it ignores all those flights executed by veterans. To complete the picture, then, here is the grand total: the Skylab 4 mission orbited the 100th "generic" spacenaut in November 1973, STS-8 with Challenger included the 200th generic spacenaut in August 1983 and STS-22 with Challenger (again!) was responsible for the 300th generic spacenaut in October 1985. All of these were US flights, and the Shuttles' contribution is evident. Finally, with the Soyuz TM-3 mission, 321 generic passengers to date have been transported to orbit on 114 space flights.

YARON SHEFFER
Texas, USA

Ariane 5/Hermes

Sir, I am baffled why Ariane 5 is being upgraded by uprating the boosters and core stage to launch up to 21 tons to orbit from 18 tons. A consequence of this and other factors is a reduction in usefulness of Hermes. Surely the obvious way to go is in the same manner as Ariane 4, which by the time of Ariane 5 launch will have given ESA plenty of flight experience with differing combinations of boosters. I suggest:

Ariane 5-2, Core-stage + 2 boosters
Ariane 5-3, Core-stage + 3 boosters
Ariane 5-4, Core-stage + 4 boosters
Ariane 5-6, Core-stage + 6 boosters

Obviously some structural strengthening would have to take place, hard points for an extra booster etc, and dozens of other areas would have to be reappraised with a corresponding increase in structure mass; but this is a small price to pay if at a later date one has to consider this option or develop a new vehicle entirely. Surely, with the high cost of development it makes sense to get the most out of it for the minimum expenditure.

Currently (July 1987), the flexibility of Hermes is seriously comprised. Although the payload remains approximately the same, it is making the best of a bad job. Logically, Hermes should be able to take Eureca to and from orbit, to service and replace equipment on Eureca and the Polar Platform, and if required (in an emergency) to fly limited Space Station missions. Thus, it would complement and back up an unreliable Shuttle service (based on four orbiters) which will be heavily committed to the US military or Space Station duties and probably US interests, before the equipment of other nations would be flown or retrieved.

R. HARVEY
Portsmouth, England

Energia Payload

Sir, I read with interest the articles in the August issue of ***Spaceflight*** on the Energia launch system. There does not seem to be a very clear indication of the nature of the payload on the test flight and I wonder if I could use your pages for a little speculation as to what it may be.

The main facts seem to be that it had its own propulsion system and that its thermal signature on re-entry implies it was either large and complex or that it contained a lot of propellant. An additional feature I found puzzling at first is that it seems very slender, scaling at around four metres diameter which is about the same as the Proton launcher, whereas one would have expected almost double that if the massive 100 tonnes capability into low-Earth Orbit is to be used effectively.

I think all these facts could be explained if it were an upper stage for Geostationary, Lunar, and Planetary missions. The payload for such misions would be between 20 and 35 tonnes. This is a little greater than Proton's payload into low-Earth orbit, but close enough to explain why the payload diameter is effectively the same.

If this identification is correct it would allow the Soviet Union to place and maintain Mir class space stations in geostationary and Lunar orbits. The geostationary orbit station could support the Solar Power Satellite programme, whereas the Lunar orbit station could support surface operations.

C.M. HEMPSELL
Hertfordshire, England

Thoughts on Energia

Sir, The Energia booster has been drawn [1] showing a nozzle diameter of three metres. This leads us to conclude that the Soviets have developed a powerful engine of 600 tons thrust using a single nozzle, thus making it almost comparable with the F-1 engines used on the Saturn 5 and in contrast to the use of a large number of engines as on the extinct TT5/G booster.

The LH_2/LO_2 engines of the core vehicle are more powerful than the US Space Shuttle main engines and one should consider a minimum thrust rating of 200 tons for each engine giving the Energia a total minimum thrust of 3200 tons.

If this booster is to be used for interplanetary probes then one might expect a version of the 1994-1996 Mars missions [2] to be launched by it, where a rover, ascent module and orbiter could all be launched together.

One might expect the Soviets to think also of probes to the outer Solar System (Jupiter and Saturn), making use of the Voyager results. For example, the experience gained from the Venus Landers could be exploited in penetrating the atmospheres of these planets to greater depths than the US Galileo probe is intended to go. Together with the balloon experience on Venus and that projected for Mars, some very interesting Jovian missions can be proposed.

If a manned space station is to be placed in a Sun-synchronous orbit for dedicated Earth observations, then one might expect a Soyuz TM with a toroidal tank to be launched on an SL-16 to a 900 km orbit.

Pictures of the Energia launch pad show that the pad has the same height as the two-stage rocket. If three stage stacked versions are to be used then a different tower is to be expected. It seems that such verisons of the rocket will not be tested in the near future.

M.Q. HASSAN
Baghdad, Iraq

References
1 Aviation Week & Space Technology June 1, 1987
2 Aviation Week & Space Technology, May 25, 1987

CORRESPONDENCE

Soviet Openness

Sir, Many thanks for the latest issue of ***Spaceflight*** – there was much interesting material to read. It is gratifying that the Soviet Union is being more open these days and good to see a letter from the Soviet Union.

I had hoped to have attended the Paris Air Show this year. It looks like I missed a treat. Last time I went the Soviet exhibition was not bad but not fantastic – this year it looks like it was very good indeed.

CHARLES W. EVANS-GUNTHER
Flint, North Wales.

Launch Announcement

Sir, I was disappointed to see two errors in the July issue of ***Spaceflight***. The impending launch of Energia *was* announced on Radio Moscow at 0600 UTC on May 15, contrary to Mr Kidger's assertion *(p.5)* and the small spaceplanes were not launched from Tyuratam *(p.6)* but originated from Kapustin Yar.

G.E. PERRY, M.B.E.
Kettering, England

Mir in English

Sir, Since the launch of the Soviet Union's latest orbital station, I have noticed that the western press has rendered 'Mir' into English as 'peace'.

However, I understand that the word 'Mir' describes in Russian an ideal peasant community (akin to the romanticised concept we have of a medeival English village). Such a community played a crucial part in the thoughts of several prominent Russian social philosophers of the last century (e.g. Tolstoy and the great anarchist theoretician Kropotkin) and represented for them a millenial vision of the perfect society to come.

Given the fact that the astronomical 'Mir' is designed to serve as a nucleus of a 'community' of laboratories and spacecraft may I suggest that a more accurate translation of its name is 'Commune' or perhaps (at a pinch) 'Harmony'?

SIMON BARNSLEY
Solihull, England

Mir Dockings

Sir, Reports about the Soviet Mir Space station have been given recently in both ***Spaceflight*** and ***JBIS***. I would like to offer some information on various questions that have come up.

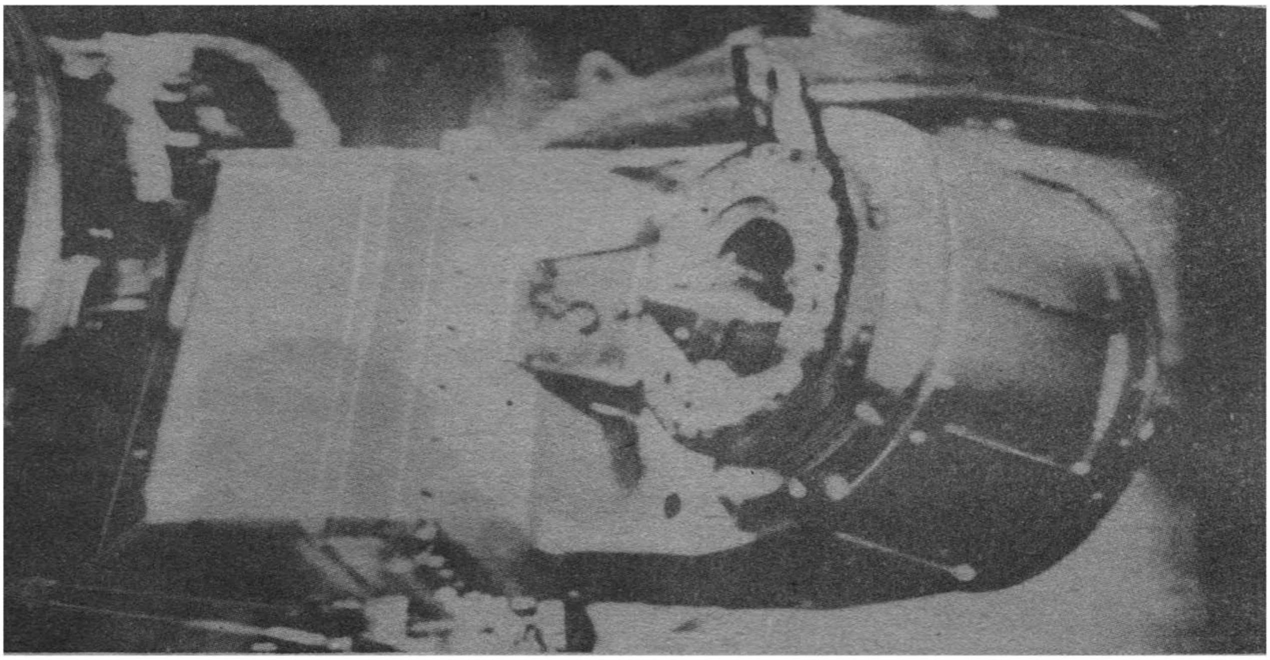
Lucien van den Abeelen (***Spaceflight***, May 1987 pp.184/5), says that the three-petal structure of the manipulator socket on the Mir is not visible on photos of the flight model of Mir. Indeed, the structure was visible on photos shown during the Soviet presentation at the IAF Congress last year in Innsbruck. So, no EVA spacewalk is necessary to prepare the socket for use as previously suggested.

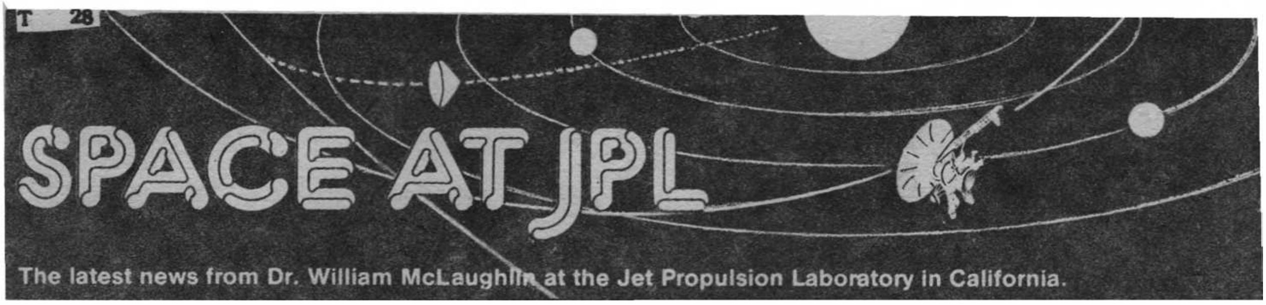
All connectors in the forward docking system of Mir have been relocated so that the system is rotated by 45 degrees around the roll axis of Mir. If Soyuz-TM has its docking system arranged in the same manner as Soyuz-T, its solar panels will be inclined by 45 degrees to Mir's solar panels. A model of Mir at the Aerosalon in Paris this year showed this configuration. If this is also true for the small scientific modules, their solar panel plane remains inclined after they have been re-docked to one of the lateral ports, since the connectors there are also rotated. All of this is necessary so that the connectors of the docking system of the modules face their counterparts before and after redocking, when they are swung around the axis of the manipulator socket.

It should also perhaps be made clear that the photo given in ***Spaceflight***, March 1987 p.104, and in ***JBIS***, May 1987 p.202, shows a training model of Mir in the cosmonauts training centre and not the flight model.

DIETRICH HAESELER
Oberhaching, West Germany

The manipulator arm of the module which is designed to engage a three-petal socket on Mir's multiple docking assembly. After docking at the forward docking port of Mir, the arm would engage the socket and hold the module as its main docking probe is retracted and it swings round the socket through 90 degrees to re-dock at a lateral port. The picture was taken from the projection screen during a Soviet presentation at the 1986 IAF Congress and consequently lacks good definition. *D. Haeseler*





Our Galactic Home

The theme of much of the material presented in this column has been the exploration of the Solar System, the primary task that JPL performs for NASA. Normally, the Solar System is considered as a domain unto itself - even visiting comets are of a domestic vintage, being obtained from the Oort-cloud warehouse in the outer Solar System. But the Sun is a star, among 10^{11} in our Galaxy, and the Galactic environment is increasingly recognised as furnishing more than a passive background to our existence.

Before examining the nature and extent of Galactic influences, we might pause to look beyond the Galaxy to the universe at large. One of the most dramatic interactions, or lack thereof, is represented by the dark sky at night. It is easily seen that if a line-of-sight from an observer is extended far enough in any direction it will eventually terminate on the surface of a star, if the universe were infinite and Euclidean and more-or-less uniformly populated with stars. Thus, the night sky would not be dark but, rather, as bright as the surface of the Sun! The tension generated by this somewhat Malthusian thought experiment and reality is known as "Olbers' paradox" in recognition of the 1823 essay by Wilhelm Olbers (1758-1840) which popularised the subject. See Stanley Jaki's scholarly book, *The Paradox of Olbers' Paradox* (1969), for a history of the topic.

Many explanations for Olbers' Paradox have been proposed. It does not help to assume the existence of intervening clouds of material to block the incoming starlight; for an Olberian universe in thermal equilibrium these clouds would re-radiate the energy at the same temperature (of course, in our actual universe dark clouds of interstellar material do exist). Most current explanations rest upon the expansion of the universe and its finite age. The former factor weakens the contribution of distant stars due to the redshift of their observed light. The latter factor strikes at the heart of the Olberian formulation because the light from very distant stars has not had time to get here.

Another interaction of the universe with our local environment was proposed by the Austrian physicist Ernst Mach (1838-1916) who objected to Newton's concept of absolute space. He replaced this abstract conception with the idea of motion relative to the bulk of matter in the universe. Einstein seems to have been the one who subsumed Mach's speculation under the name "Mach's principle". This vein of thought has undergone many transformations, and the expression "Mach's principle" is often applied to connections between local dynamics and the large-scale structure of the universe.

Before passing on to the subject of the Galactic environment *per se*, we would be remiss not to mention an area of considerable current interest: the so-called anthropic principles. The "Weak Anthropic Principle" quite reasonably states that, since we do indeed exist, we should not be surprised to observe in the universe certain phenomena and conditions which are necessary for that existence. Hence, the universe must be rather large in order for carbon-based creatures like us to inhabit it. This follows from the need for several thousand million years of evolution – astronomical, chemical, and biological – for our development, and in this time the expanding universe would grow to several thousand million light years in extent.

The real fun begins when one entertains the "Strong Anthropic Principle" of Brandon Carter. "The universe must have those properties which allow life to develop within it at some stage in its history." The "must" is used in an *a priori* sense and not the *a posteriori* statement of the Weak Anthropic Principle. That is, a universe without life is not possible according to the Strong Anthropic Principle. This is strong stuff and there is not space to do it justice here. We will return to it in a later column, particularly with regard to the search for extraterrestrial intelligence (SETI). The interested reader may wish to consult *The Anthropic Cosmological Principle* (1986) by John Barrow and Frank Tipler. Surely this delightful and informative work will become a classic of scientific and philosophical exposition.

The story of some of our interactions with the Galaxy is well told in a recent release in the *Space Science Series: The Galaxy and the Solar System* (U. of Arizona Press, 1986), edited by R. Smoluchowski, J. N. Bahcall, and M.S. Matthews. A few of the 22 papers in this work will be touched upon. It should be born in mind that the sum of the papers does not form a consensus, and there is still considerable disagreement on matters of fact and interpretation in this growing field of "astronomical ecology".

First, it will be worthwhile to review some basic facts.

The Galaxy is primarily a collection of stars and gas measuring about 30 kpc in diameter (one parsec is approximately 3.26 light years and a kpc is 1000 parsecs; for comparison, the Sun is eight light minutes from the Earth, and the nearest star is 1.3 pc distant). In its other dimension, the system is about 2 kpc in thickness. This disk is not homogeneous but has spiral arms and resembles, in many respects, the nearby (almost 700 kpc) Andromeda galaxy. The flattened disk of the Galaxy is complemented with a less-dense spherical halo of more than 100 globular clusters – compact associations of 100,000 or so stars, which are among the oldest structures in the Galaxy.

The Solar System is located 7-10 kpc from the centre of the Galaxy and travels around the centre in a nearly circular orbit about once every 200 million years. Hence, the Solar System has completed approximately 20 galactic revolutions since the Earth was formed.

Frank Bash of the University of Texas has contributed to the collection a paper which more closely details the motion of the Sun within the Galaxy. In its 4500 million year lifetime, the Sun has encountered several large molecular clouds and crossed the spiral arms of the Galaxy about 17 times. Using the method of numerical integration on a computer, Bash forecasts the motion of the Sun for the next 100 million years. He modeled the major features of the Galaxy, including spiral arms, which affect the solar motion, but did not include the gravitational effect of individual stars; (close encounter with a star would materially affect the orbit and vitiate the integration).

If one approximates the resulting solar orbit with an ellipse, it is reasonably close to being a circle (the eccentricity is 0.07). The Sun will next reach its closest approach to the Galactic centre in only 15 million years and should encounter a spiral arm in about 50 million years. The Sun's orbit does

not lie exactly in the plane of the Galaxy but has a slight inclination which carries our star almost 80 pc above or below the plane: the maximum distance, which will be reached in about 14 million years. The vertical oscillations yield a crossing of the Galactic plane about every 33 million years.

Over two-thirds of the interstellar gas in the Galaxy is believed to be in molecular form, and most of this gas is collected into giant molecular clouds (GMC). A typical GMC has a mass from one hundred thousand to over one million times that of the Sun and ranges in size from 20 pc to 100 pc. N.Z. Scoville and D.B. Sanders of the California Institute of Technology estimate the frequency of penetrating encounters (four million or so years in duration) of the Sun with GMCs to be about once every 1000 million years. Hence, they conclude that such encounters cannot be responsible for short-term periodicities in the geological record which some investigators claim to have detected (more on this later).

P.C. Frisch and D.G. York of the University of Chicago have examined the local solar environment and conclude that we are currently in a region of the Galaxy that is relatively free from interstellar gas and dust. However, we are headed for a region which is more densely occupied with interstellar material. In 100,000 to one million years we may encounter such dense material. Passage through a cloud core (these would be objects smaller than the GMCs described above) might suppress the solar wind (which flows radially outward from the Sun) and perturb the atmosphere of the Earth sufficiently to alter the climate.

Cosmic rays consist of high-energy particles which course through the Solar System. The chief species is the proton, but heavier nuclei are also present. Cosmic rays originate locally, in the Sun, and in interstellar regions. Two papers, by J.R. Jokipii (University of Arizona) and K. Marti (University of California at San Diego) and by D.D. Clayton (Rice University) *et al*, discuss the possibility that a supernova may have occurred near the Solar System in the not too distant past, based upon evidence from cosmic rays. No firm conclusion can be reached concerning this hypothesis, but a supernova within a few tens of parsecs of the Suns, perhaps 100 thousand years ago, would have had interesting consequences. As Clayton *et al* state: "The event itself would have been quite dramatic, potentially 0.1 per cent to 1 per cent as bright as the Sun, a possibly stressful situation for nocturnal creatures and the emerging human race alike". In comparison, a brightness of 0.1 per cent of the Sun would correspond to the light from 400 full Moons.

A significant fraction of *The Galaxy and the Solar System* is devoted to the subject of comets. In order to appreciate the nature of interactions between comets and the Galaxy it is necessary to understand something of the structure of the cometary system.

In 1950 the Dutch astronomer Jan Oort hypothesised the existence of a cloud of comets in the outer Solar System that serves as the source of comets which visit the inner Solar System. Each year, in general, several such visitors appear, and some of them are captured by planetary gravitational action, remaining, like Comet Halley, as periodic comets. Oort was led to his conclusion by examining the computed orbits of numerous long-period comets.

The Earth is currently in a region of the Galaxy that is relatively free from interstellar dust.

The Oort cloud is still only an hypothesis, but it has proved so fruitful in explaining the observed facts that most astronomers find it highly credible. The parameters describing the Oort cloud are, not unexpectedly, the subject of some uncertainty. Approximately 10^{12} comets reside in a zone stretching from 20,000 out to 50,000 AU from the Sun. One AU, or astronomical unit, is the mean distance from Eath to Sun, and there are 205,265 AU in one parsec; the Oort cloud is sized on the order of a few tenths of a parsec. There is some evidence for an inner Oort cloud extending as far in as the orbits of Neptune and Pluto.

The origin of the Oort cloud is also uncertain. The most likely source of the material is the set of processes which yielded the Sun and planets. However, proponents of an interstellar source for some comets are still active. Two major sub-divisions of the first theory (non-interstellar origin) exist: (1) formation of the cloud in its current location, (2) formation of comets in the Uranus-Neptune region of the Solar System and subsequent ejection into the Oort region by close encounters with planets.

M.V. Torbett of the University of Kentucky and P.R. Weissman of JPL examine, in separate papers, the influence of the Galaxy upon the structure of the Oort cloud. The tidal (gravitational) forces exerted by the Galaxy will place an outer limit on the extent of the region of comets: about 100,000 AU. Perturbations from nearby stars place a similar limit on the size of the Oort cloud. But, as mentioned above, the cloud seems to extend only half as far out as it might. The missing limiting factor might be the GMCs which, if encountered often enough, could shape the Oort cloud to its current dimensions. In addition, encounters with GMCs have randomised the orbits of the comets comprising the Oort cloud.

The most dramatic theme contained in the book is the attempt to identify cataclysmic events in Earth's history, such as sudden mass extinctions of biological species, and explain them through cosmic phenomena, in particular, showers of comets.

M.R. Rampino (New York University) and R.B. Strothers (Goddard Institute for Space Studies) have reviewed the evidence that terrestrial impact cratering and global tectonic phenomena are periodic in nature. Time-series analysis has indicated the possibility of two major periods: one of about 33 million years, the other about 260 million years. They state that these geological periodicities have manifested themselves for at least 600 million years, and maybe 1,800 million years. There are four popular explanations as to the cause of the periodic terrestrial cratering, presumably resulting from cometary (and asteroidal) impacts. Two of the explanations postulate the existence of currently unknown intruding bodies which disturb the Oort cloud and induce comet showers. One of these theories holds the intruder to be Planet X beyond the orbit of Pluto while the other postulates a distant companion star to the Sun. A third intrusive-body theory claims that stars occasionally passing through the solar neighbourhood are the perturbative source of cometary showers. Rampino and Strothers favour a fourth cause as an explanation of the 33 million year cycle: the vertical oscillation of the Solar System through the plane of the Galaxy. At times of passage through the plane, encounters with molecular clouds would be more probable, stimulating comet showers from the Oort cloud and increased impact with Earth. The longer (260-million year) period may correspond to passages of the Solar System through a galactic spiral arm.

E.M. Shoemaker and R.F. Wolfe, both of the US Geological Survey, look at mass extinctions of biological species and terrestrial cratering over the last 250 million years. They detect a probable periodicity (of about 31 million years) and correlation between the two sets of events. Their conclusion is that gravitational perturbations from occasional passing stars are the most likely mechanism producing the comet showers responsible for cratering and extinctions.

The possibility of the existence of a tenth planet, beyond the orbit of Pluto, is examined by J.D. Anderson and E.M. Standish, Jr. of JPL. They look at dynamical evidence for the hypothetical Planet X through analysis of the orbits of Uranus, Neptune, and the Pioneer 10 spacecraft. It is concluded that within the accuracy of available measurements, no unknown forces appear to be acting on these three denizens of the outer Solar System. However, they intend to increase the accuracy of the measurements and add Pioneer 11 to the set of test objects, so the issue remains an area of active research *(see also p.323 of this issue)*.

Space at JPL

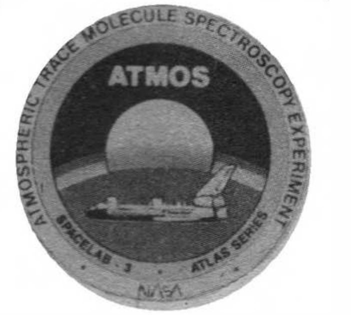
Atmospheric Molecules

If one were to call out the physical factors that distinguish Earth from the other planets, our atmosphere and the oceans might head the list. The present atmosphere of Earth was formed in large part by the action of biological processes, particularly those involving plant life, and so it is not surprising that we extol its virtues; the atmosphere is a custom-made product. However, the partnership with life may not always be beneficial nor benign. There are indications that some recent human activities may be introducing substances into the atmosphere that can alter its physical properties in a way that could be harmful to the biosphere.

The Atmospheric Trace Spectroscopy (ATMOS) experiment was flown as part of the Spacelab 3 mission on the Challenger from April 29, 1985 to May 6, 1985 (see the June 1984 edition of this column for a pre-launch description). The two basic purposes of ATMOS were: (1) to compile an atlas of the molecules found in the atmosphere, and (2) to establish profiles of their concentration at various altitudes and latitudes. The motivation for the experiment was to provide data for modelers of the atmosphere so that they can gauge the origin, extent and consequences of trace molecules in our atmosphere. Of course, special interest will be focused on any results which are related to human activities.

The energy of a molecule can be represented as the sum of the motion of electrons relative to the nuclei, the vibrations of the nuclei, and the spatial rotation of the whole molecule (and of course, the translational energy). ATMOS based its detection of molecules on the observation of the amount of sunlight absorbed by those molecules in vibrational and rotational modes; the patterns of absorption are characteristic for each molecular species and serve as "fingerprints".

The principle of design for the observations was simple: look directly at the Sun through a portion of the atmosphere and measure the amount of solar radiation subtracted, as a function of wavelength, by molecules in the column of atmosphere between Sun and instrument. The instrument for the

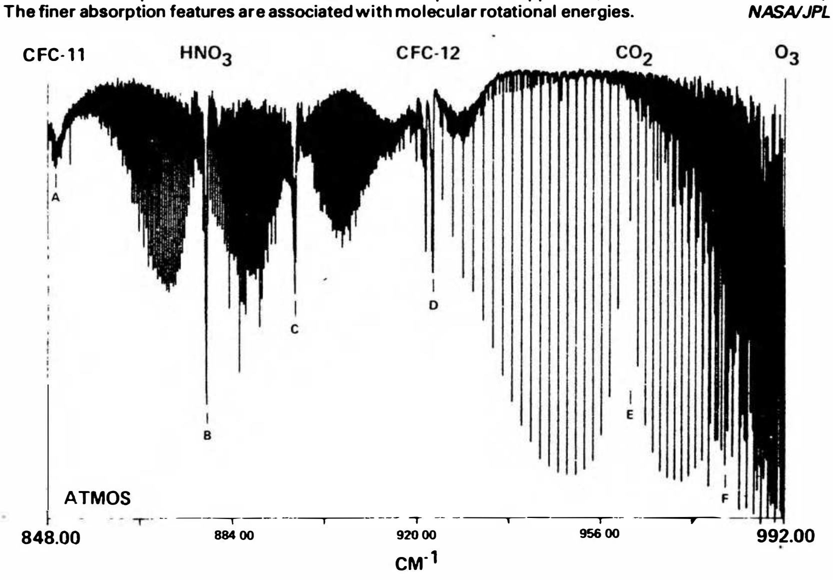


The ATMOS experiment on-board Spacelab 3 in 1985 measured concentrations of 25 molecular species. The experiment is scheduled to fly again as part of the ATLAS series of missions.

ATMOS experiment was a 250 kg Fourier-transform spectrometer built by the Honeywell Electro-Optics Center in Wilmington, Massachusetts. Its range of sensitivity, wherein absorption lines can be measured, lies in the infrared region of the spectrum with wavelengths from 2.2 to 16 microns (a micron is one millionth of a metre and visible light ranges from 0.4 to 0.7 microns). For comparison, the Infrared Astronomical Satellite (IRAS) observed celestial objects from eight to 125 microns.

Spectroscopists, by convention, often measure spectral line locations in units of reciprocal length, cm^{-1}, rather than microns. In these units the span of effectiveness for ATMOS observations ranges from 625 cm^{-1} to 4600 cm^{-1}, and the spectral resolution of the instrument is 0.0125 cm^{-1}. Thus, over 300,000 resolution elements occupy the spectral range of interest. In other words, ATMOS is capable of obtaining a large amount of information about atmospheric molecular spectra. This is reflected by the high data rate of 16 megabits per second that the instrument generates. During operations this bit stream was passed from the Shuttle to NASA's Tracking and Data Relay Satellite (TDRS) in geosynchronous orbit, and then to a ground station. Not until the advent of modern high-speed computing was it possible to process such large amounts of data as are produced by high-resolution Fourier-transform spectrometers.

This spectral map of a region of the atmosphere was obtained by ATMOS from Spacelab 3 in 1985. Broad vibrational absorption features for several molecular species are apparent (CFC is "chlorofluor-carbon"). The finer absorption features are associated with molecular rotational energies. *NASA/JPL*



The plan for the ATMOS mission was to observe sunrise and sunset as viewed from the Challenger, when the overall mission plan permitted. The Shuttle experiences sunrise and sunset 32 times per day in the course of circling the globe. ATMOS observations of the atmosphere were made for about three minutes during each of 12 sunsets and five sunrises, yielding approximately 1000 solar spectra. Another 2000 "high Sun" spectra were made, away from the horizon, to obtain reference measurements of solar emission and absorption lines which would otherwise confuse detection of atmospheric absorption lines. Ratioing the low Sun (sunrise and sunset) and high Sun measurements brought out the atmospheric contributions.

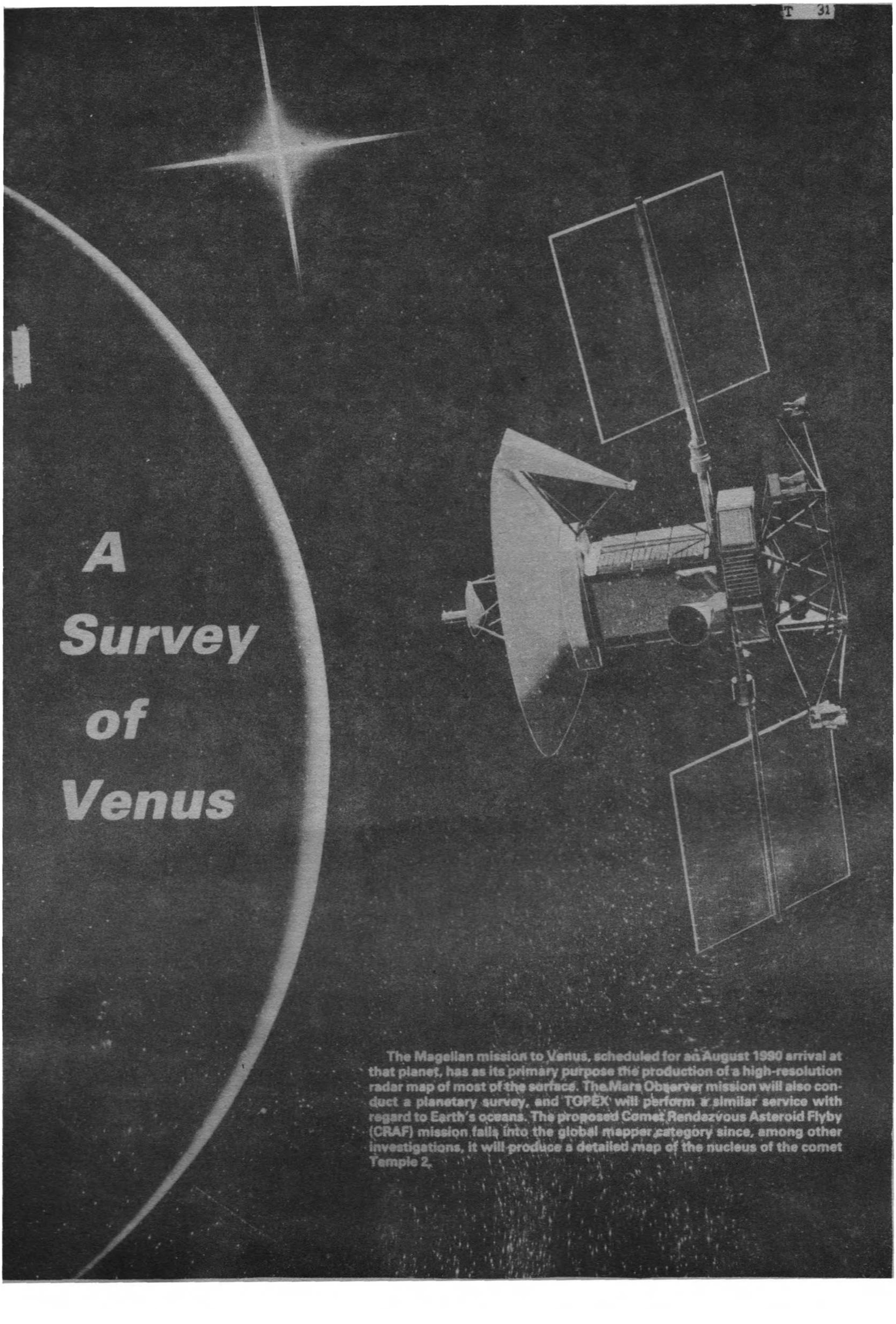
ATMOS detected and measured concentrations for 25 molecular species during the Spacelab 3 mission, four of which had never previously been measured spectroscopically in the atmosphere. Molecules were measured up to an altitude of 140 km and between the latitude band from 10 to 40 degrees N and between the latitude band from 40 to 50 degrees S.

An added bonus of the experiment was the ability to measure atmospheric wind speeds through a doppler comparison of spectral line positions from atmospheric molecules to those from residual "rest" molecules of carbon dioxide and water vapour inside the instrument!

Currently, the ATMOS project is producing the final catalogue of molecular species, contributing papers to the scientific literature (see, for example, four papers by ATMOS team members in the August 1986 issue of *Geophysical Research Letters*), making spectral measurements from the ground, and preparing for future flights of the instrument aboard the Shuttle. The next flight is listed in the Shuttle manifest for 1991.

ATMOS is managed by JPL for NASA's Office of Space Science and Applications. Fred O'Callaghan is the project manager and Dr. Crofton Farmer is the Principal Investigator. Thanks are due to Odell Raper of JPL, the Deputy Principal Investigator, who provided details of this highly successful investigation. In a subsequent column we will follow the ATMOS team to Antarctica, where, last year, they employed a ground-based interferometer at McMurdo Station in order to gather data about ozone depletion over the southern polar region.

A Survey of Venus



The Magellan mission to Venus, scheduled for an August 1990 arrival at that planet, has as its primary purpose the production of a high-resolution radar map of most of the surface. The Mars Observer mission will also conduct a planetary survey, and TOPEX will perform a similar service with regard to Earth's oceans. The proposed Comet Rendezvous Asteroid Flyby (CRAF) mission falls into the global mapper category since, among other investigations, it will produce a detailed map of the nucleus of the comet Tempie 2.

Space at JPL

Survey missions have a flavour all of their own. Your correspondent was readily able to contrast the IRAS astronomical survey in 1983 with the 1986 Voyager flyby of Uranus, having worked in immediate succession on those two missions. Both were rewarding experiences with their share of excitement. Although the Voyager encounter period extended from November 1985 to February 1986, approximately 90 per cent of the science was achieved in about 10 hours near the heart of the Uranian system. Consequently, extraordinary measures were taken to make operations perfect during this most valuable interval.

For IRAS, the metaphor that occasionally rose to mind was that of being a rower aboard an ancient galley. The inexorable drum beats were supplied by the rotation of the celestial sphere as the Earth circled the Sun and by the satellite, using up its observing programme every 12 hours, needing to be reloaded with instructions for its on-board computer. In addition, the satellite's cryogenic coolant (superfluid helium) was steadily boiling away, and with it the life of the mission. The penalty for errors or other problems was a hole in the all-sky survey, an exaction probably only slightly less painful than a lash on the back. And, in fact, steps were taken at the control centre in England and by Donna Wolff and her team back at JPL to indentify and plan to fill holes in the sky coverage. It would have been particularly unfortunate to have numerous small holes, so difficult to characterise, laced throughout the map of the sky. The final map covered 96 per cent of the celestial sphere and with a favourable topology.

The Magellan survey of Venus is accomplished by looking down rather than up, but the effort has points in common with the IRAS survey. For IRAS, the orbital plane of the satellite was designed to rotate slowly in inertial space, at about one degree per day, to keep the Sun away from the observing regions as the Earth pursued its annual path (hence, geocentrically, one would experience the "rotation of the celestial sphere" as mentioned above). The power for driving the rotation of the orbital plane in this Sun-synchronous fashion is obtained through a well-known device of orbit design, utilising the oblateness (departure from a perfect sphere) of the Earth. In the case of Venus, the planetary surface appears to slowly rotate through the effective observing region of the synthetic aperture radar (SAR) – similar to the celestial sphere's rotation for IRAS – but the causes are different.

The orbit plane for the Magellan spacecraft remains almost fixed in inertial space because Venus is nearly spherical. But the planet rotates (in retrograde fashion) about its spin axis every 243 days. Hence, the planet appears to rotate slowly (every 243 days) with respect to the spacecraft's orbit plane. The orbit of Magellan is highly elliptical and observing with the SAR is undertaken in the time (up to 37.2 minutes) when the spacecraft is close to the surface of the planet, to obtain the highest-resolution radar images. The mapping portion of the orbit occurs at altitudes ranging from a low of 250 km to a high of 2113 km; the furthest point in the orbit from the planetary surface is over 8000 km. Transmissions to Earth of the tape-recorded observations and other tasks are undertaken during the remainder of the 3.15 hour orbit (see the June/July edition of this column for a description of mission operations for Magellan).

Magellan will, like IRAS, be mapping a surface passing steadily through its observing region, and the flight team will be steadily stoking the on-board computer with observing instructions – every few days for Magellan rather than IRAS's twice per day.

So much for the tactical situation. What about the survey strategy? On IRAS, Sylvia Miller and I worked with the science team to plan a course of action. Three major items drove our strategy for IRAS: (1) The requirement to finish the survey before the estimated eight to ten months supply of liquid helium ran out, (2) circumvention of the effects of those "dead periods" when the satellite was passing through the most intense portion of the Earth's trapped radiation (the resultant noise induced in the infrared detectors made observation impossible at those times), and (3) the need to provide astronomers some time, during the course of the all-sky survey, to observe selected objects of high interest. See our paper in the January-March 1986 *Journal of the Astronautical Sciences* if the suspense is getting to you.

The strategy for the Magellan survey is dominated by geometry: the relation of the limited observing zone during each orbit to the slowly shifting planetary surface which scrolls beneath it.

The ideal mode for Magellan would have been to place the spacecraft in a low circular orbit about Venus and to utilise a two-antenna system: one antenna to perform the survey and the second to pump the data back to Earth. From a circular orbit a planetary survey could be completed in only one-half of the 243-day rotational period. However, a scheme such as this would have caused practical problems with regard to cost and spacecraft mass. The performance of the Star 48B solid rocket motor, used to insert the spacecraft into orbit about Venus, limits orbital geometries available to mission designers.

Secondary constraints are also geometrical: Venus will pass behind the Sun, interrupting the survey through disruption of the communication link to Earth; on day 90 after insertion into orbit about Venus the Sun will come between us and the planet, and as much as 28 degrees of longitude survey coverage may be affected in the time period around this event. Later in the mission Venus itself will block data transmission from the spacecraft during part of the spacecraft's orbit.

The Magellan team has formulated strategies to deal with the limitations imposed by the non-circular orbit and the occultations by the Sun and Venus. An optimistic estimate is that the survey will yield about 81 per cent coverage of the planet, while more pessimistic calculations placed the total coverage at about 74 per cent. Unlike IRAS, the Magellan spacecraft is expected to survive its primary mapping period and further coverage, in addition to more specialised investigations, will be possible.

Periapsis – the closest point to Venus in the spacecraft's orbit – is not placed at the Venusian equator but lies in the northern hemisphere at 10 degrees latitude. Therefore, survey coverage is biased toward the northern hemisphere and, in fact, coverage of the planet is expected from the north pole (+ 90 degrees latitude) down to – 67.7 degrees latitude.

In order to achieve this coverage, Magellan survey strategists plan to bias every other mapping orbit toward more southerly coverage, by choice of when they turn on the SAR for mapping. Since ground swaths of alternate orbits still overlap, no holes are created in the northern hemisphere by this strategy. Without this method, latitude coverage would extend to only –54 degrees latitude.

Having mitigated the efforts of the eccentric orbit, survey planners looked at solutions to the problems occurring when the Earth-Venus geometry resulted in occultation by Venus of a region around the apoapsis (furthest point from the planet) of the spacecraft's orbit. The basic problem is that this phenomenon reduces the amount of time available during each orbit to play back tape-recorded SAR data. Hence, less data can be gathered, resulting in less coverage during this period: from day 127 to day 166 after insection into orbit about Venus.

The occultation period varies from 0 to 57.3 minutes per orbit in this mission phase. When occultation exceeds 14 minutes, the southerly bias of alternating orbits must temporarily cease, and all swaths will begin at the north pole and proceed as far south as possible with regard to data-collection limitations imposed by the play-back capability.

During the extended mission, after the nominal mission has been completed, strategies have been formulated to extend survey coverage to the south pole, to provide stereo images of selected areas of the surface, and to study in more detail objects of high scientific interest.

OCTOBER 1987 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

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Vol. 29 Supplement No. 2 October 1987

SPECIAL **30TH ANNIVERSARY of SPACE EXPLORATION** ISSUE

This month *Spaceflight* magazine presents a major feature on the first 30 years of the space age. Throughout these years, *Spaceflight* has been reporting news and developments in space to its international readership, being already one year old when Sputnik I was launched on October 4, 1957. In a special 26-page section beginning on p.54 of this issue we seek to recapture the spirit of the times from the photographic record and *Spaceflight's* own written reports spanning the past 30 years.

Coinciding closely with this 30th Space anniversary is the week-long 38th Congress of the International Astronautical Federation (IAF) at Brighton, Sussex (on 10-17 October). This meeting is being hosted by the British Interplanetary Society, which is the world's longest-established society devoted solely to the promotion of astronautics, the UK voting member of the IAF and publisher of *Spaceflight*.

Contents

***Spaceflight* Office:**
27/29 South Lambeth Road, London, SW8 1SZ, England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22-26 Farringdon Lane, London EC1R 3AU. Tel: 01-253 3135.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L. Ltd., Aylesbury, Buckinghamshire, England.

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Front Cover: The Apollo-Soyuz Test Project (ASTP) of July 1975 remains to this day a unique example of joint Soviet-American space activity. No mission is more complex than sending men into space and ASTP involved additionally the standardisation of docking techniques between two very differently conceived spacecraft – the Apollo command-service module and a Soyuz spacecraft. Further details appear on *p.72.* Our photograph shows the US commander Tom Stafford and the Soviet commander Alexei Leonov during the 43 hours of joint activity when they worked and ate together and visited each other's spacecraft.

SPACE

Looking To Year 2001

by Michael Wilhite

When *2001: A Space Odyssey*, appeared on the cinema screens in 1968, it showed Arthur C. Clarke's vision of what the next century held for space flight, to the astonishment of the world.

The world will still be astonished by what 2001 holds. Developments of the next decade will determine who is on the 'high ground' at the turn of the century.

In this article, Michael Wilhite takes a look at the space programmes of different countries and identifies the main ongoing developments in launch vehicle capability and manned space operations.

Inside the Flight Control Centre during a Soviet manned space mission. *TASS*

The Promise of Energia

The maiden launch of the Energia rocket by the Soviet Union at 7.30 pm Moscow Time on May 15, 1987, marked the first time a very-heavy lift launch vehicle has been flown since the American Saturn V made flight to the Moon possible.

The 220,000 pound payload capability of Energia will be used to place large satellites and space station segments into orbit during the 1990's. A third stage for the Energia is under study which will lift 330,000 pounds into orbit. But the primary feature of the new Soviet rocket is its role as the booster for the Soviet Space Shuttle.

When used as an unmanned booster, a 120 ft strap-on payload canister runs the length of the 198 ft tall rocket. The canister will then be replaced by the shuttle during manned operations.

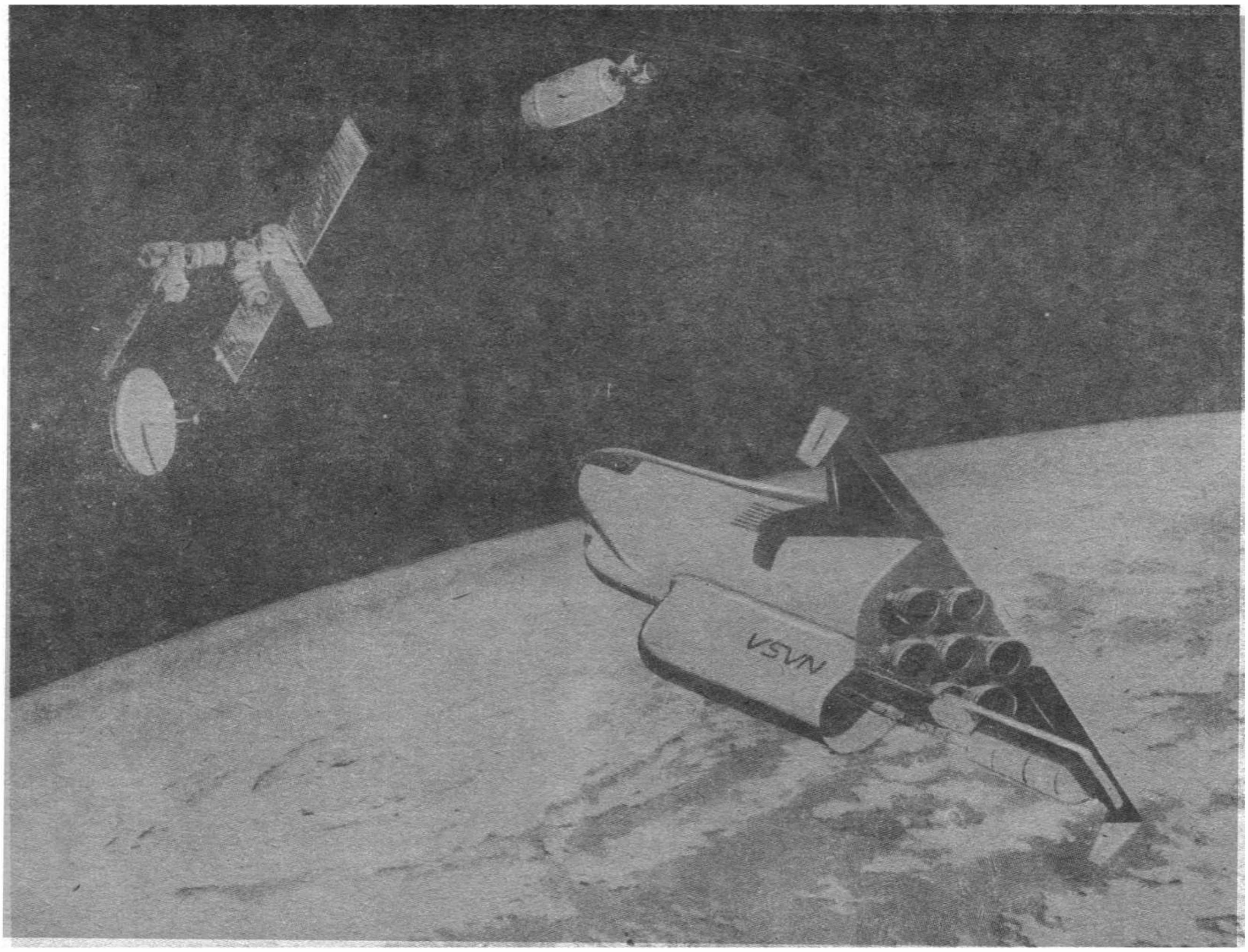
The Soviet shuttle relies on the engines of the Energia to reach orbit, since it carries no engines of its own. This gives the Soviet shuttle a slight payload capability advantage over the US shuttle system. The Soviet version is expected to lift up to 66,000 pounds of cargo.

The first shuttle launch is likely in 1990, and will be unmanned. Cosmonauts will board the shuttle in 1991 or 1992 for a two-year test phase.

Fully operational by 1994, the Soviet shuttle will initially be used in conjunction with the growing Mir space station.

Unlike the US Space Transportation System, the components of the Energia system are a family of individual launchers. The Energia uses four SL-16 boosters as strap-on rockets. The SL-16 has been tested successfully following severe development problems in 1984.

The Energia was first stacked on new Soviet launch facilities in late 1983 and was originally covered by camouflage netting. Following several successful launches of the SL-16, Ener-



A Shuttle 2 Orbiter approaches a space platform. The distinctive features of this orbiter stage of the two-stage Shuttle 2 system include the payload canister arrangement, the tip fins at the wingtips and the multiple engines. *NASA*

gia's engines were test fired for several seconds on the launch pad in March 1987.

Along with its current rockets, the Soviet Union will have the most impressive launch vehicle inventory of the 1990's.

Development of the Soviet shuttle has had its problems. Flight development tests at the Ramenoskoye flight test centre near Moscow were halted when a Bison Myasishchev Mya-4 bomber, carrying the shuttle piggyback, skidded from the runway and became stuck in the mud.

Drop tests began in early 1986. During the descent phase, the Soviet shuttle uses two jet-engines to assist in shallower and safer landings.

Soviet Manned Spaceplane

Development of a small spaceplane has been well underway over the past decade and the first manned launch of the vehicle is expected soon. The spaceplane will replace the Soyuz-TM spacecraft in 1991 as a crew and limited-cargo transport to Mir.

Test phases of the spaceplane have been well-documented. The most recent ended on December 19, 1984 when the fourth and last one-third scale spaceplane was flown. Cosmos 1614 was launched from Kapustin Yar, orbited once, and parachuted into the Black Sea. The flight was similar to its immediate predecessor, Cosmos 1517 on December 27, 1983.

Two earlier flights, Cosmos 1374 on June 3, 1982 and Cosmos 1445 on March 15, 1983, parachuted in the Indian Ocean, south of the Cocos Islands.

The operational spaceplane will be launched on the new SL-16 launch vehicle.

Large Space Station

Development of the Mir space complex is in its infancy, as the first specialised research modules, such as Kvant, are attached. Each module is expected to be used for only a year or two before being replaced by another.

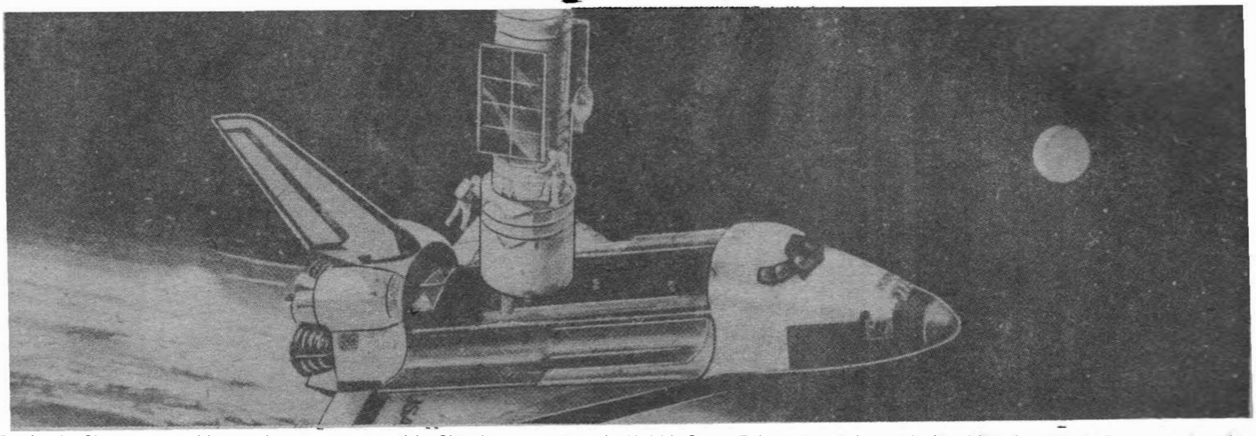
The launch rate of these modules will steadily increase into the next decade. They are launched by Proton boosters, which have also been offered for international commercial use along with the SL-4 Soyuz launcher and the Vertikal sounding rocket.

Despite two Proton launch failures in early 1987, the Proton has suffered no major delays, as have other world launch vehicles. The Proton will continue to play a major role in the Soviet space programme through the 1990's.

During the mid-1990's Proton launches will decrease as the Energia rocket and Soviet shuttle begin to launch segments of an advanced space station. This new space station continues the evolution of the Salyut and Mir programmes that began two decades ago.

By the turn of the century, the Soviet Union will have a most advanced space programme. The Energia rocket family will be the primary launcher for both manned and unmanned spacecraft. Soviet cosmonauts will either board spaceplanes or shuttles for their journey to the largest space station in orbit.

In 2001, cosmonauts will be just months from landing on the Moon, and just years from stepping on Martian soil.



But for the Challenger accident and postponement of the Shuttle programme, the Hubble Space Telescope would now be in orbit at the start of 15 years of intensive observation. The telescope will be unmanned, its operations being directed from the ground. As shown here, astronauts will arrive at the telescope to carry out in-orbit maintenance or to replace instruments or other modules.

Space Policy in the United States

No event has had such a great effect on US space policy as the Challenger Space Shuttle accident in January 1986. The goal of US space policy now emphasises expendable launch vehicles, rather than the space shuttle, as the primary means of launching commercial satellites.

A major change in the American space programme is the growing influence on policy by the Defence Department and subsequent limitations on NASA's input. Already, this has threatened aspects of international cooperation in the space station programme.

The only positive policy made since the Challenger loss was the authorisation of a replacement orbiter. The new shuttle will join the fleet in 1992. Resumption of shuttle launches is expected in the second half of 1988. The current launch date has been set for June, but may possibly slip a few months.

Shuttle payloads in the early 1990's will primarily be military and scientific with commercial payloads slowly switched to expendable boosters.

The cancellation of Spacelab missions has severely disrupted many space science projects. Only two Spacelab missions, one Japanese and one West German, have been scheduled over the next five years.

Shuttle launch facilities at Vandenberg Air Force Base will also remain closed for the next few years. Space shuttle launches to polar orbit are unlikely before 1992.

International Space Station

Re-evaluation of the space shuttle system will lead to a safer manned spacecraft, but re-evaluation of the space station has led to a shrinking programme.

Construction of a scaled-down version is currently scheduled to begin in late 1994 and will not be manned permanently until 1996. Initial completion in 1998 will end phase one of the programme.

Phase one construction includes a single transverse boom, four pressurised modules, solar panels and a mobile servicing centre.

International participation in the space station project has been jeopardised by the growing desire of the Defense Department to secure the right to conduct military activities on board. A compromise between NASA and the Defense Department will establish the future role of Europe, Japan and Canada in the space station.

Return of Expendable Launchers

The goal of using the space shuttle as the primary US launch vehicle vanished along with Challenger. In November 1986, NASA Administrator James C. Fletcher called for an inventory of expendable rockets to compensate for the reduction of shuttle launches in the early 1990's.

But further problems developed following the launch failures of a Titan 34D and a Delta rocket during 1986. Despite these failures, NASA plans to

Small-lift launch vehicles: 1990-2001.

			Payload (lb)
United States			
	SCOUT	(1960)	400 LEO 180
China			
	LONG MARCH 1-C	(1970)	1,320 LEO 594
India			
	ASLV	(1987)	2,000 LEO 900

Medium-lift launch vehicles: 1990-2001.

Soviet Union				
	A-2 SOYUZ	(1961)		16,500 LEO 7.425
	C-1	(1964)		3,300 LEO 1.485
	F-1-m	(1966)		11,025 LEO 4.961
	F-2	(1977)		17,200 LEO 7.740
United States				
	ATLAS-CENTAUR	(1966)	4.500	10,000 LEO/4,150 GEO
	ATLAS-F POLAR LAUNCH	(1977)		3,300 GEO
	DELTA 3920	(1982)	3.42	7,610 LEO/2,830 GEO
	DELTA 2 6925	(1988)	3.951	8,780 LEO/3,190 GEO
	DELTA 7925	(1990)	4.422	9,830 LEO/3,560 GEO
	ENHANCED DELTA 2	(1990)	5.000	11,110 LEO/4,010 GEO
Europe				
	ARIANE 40	(1988)		4,190 GEO
	ARIANE 42P	(1988)		5,733 GEO
	ARIANE 44P	(1988)		6,615 GEO
	ARIANE 42L	(1988)		7,056 GEO
	ARIANE 44LP	(1988)		8,158 GEO
	ARIANE 44L	(1988)		9,260 GEO
China				
	LONG MARCH 2	(1974)	1.984	4,410 LEO
	(Long March 2 has several configurations)			
	LONG MARCH 3	(1984)		3,000 GEO
Japan				
	H-1	(1987)		1,210 GEO
India				
	PSLV POLAR LAUNCH	(1989)		2,000 LEO

return to the commercial space market by using a commercial version of the military Delta 2 rocket to compete with the European Ariane, the Soviet Proton and the Chinese Long March 3.

Beginning next year, the new Titan 4 will duplicate the shuttle's capability, and a new heavy-lift vehicle, capable of launching 150,000 lb, should be available in 1993.

But NASA's participation in the development of the Advanced Heavy-Lift Launch Vehicle will be limited, with the Defence Department playing the major role and reflecting the military's new role as leader of the US space programme.

NASA does however plan to study a shuttle-derived heavy-lift launch vehicle for use in the 1990's, and uprated versions of the Titan, Atlas, Delta and Scout rockets will be used during the 1990's as primary launch vehicles.

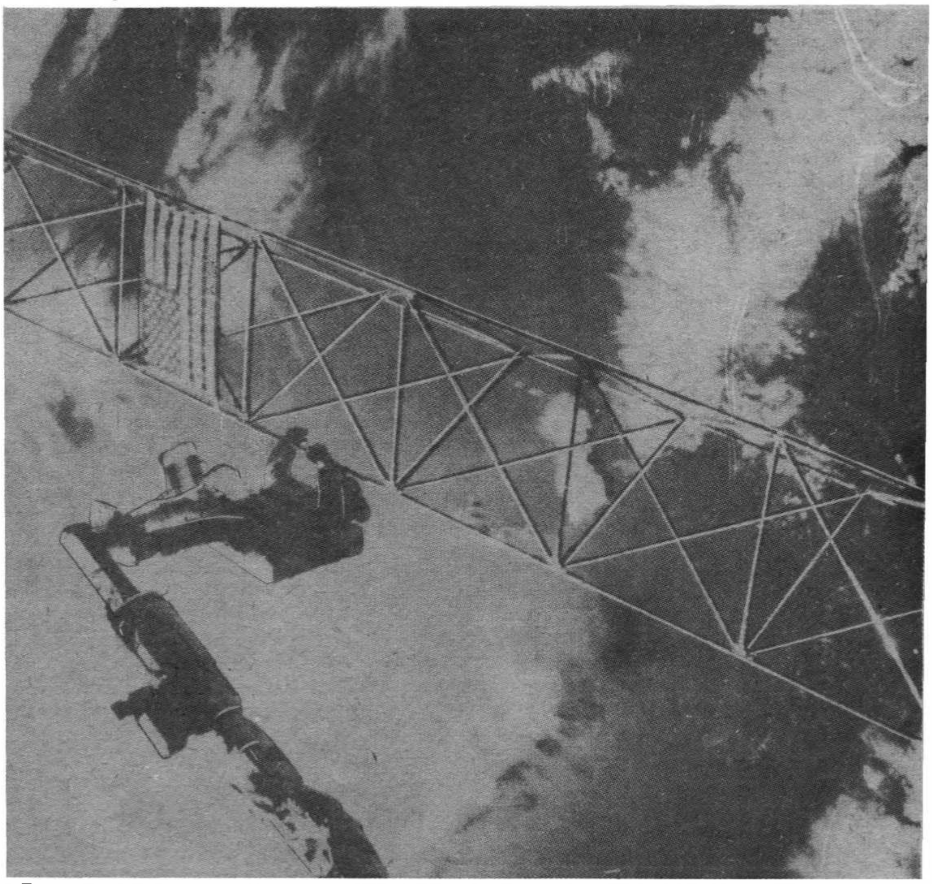
Interest in small-life launchers is growing among businesses and at least two private American companies plan to launch small satellites.

National Aerospaceplane

Development of an air-breathing Aerospaceplane is planned for the 1990's but operation of such an advanced runway-launched craft is not expected until well after 2001. A decision to build the hypersonic transport will be made in 1989, but a parallel project could bridge the gap between the space shuttle and the Aerospaceplane. This, the Shuttle 2 project, will use spaceplane project research and a more conventional rocket propulsion system.

The Shuttle 2 will operate less expensively than the current shuttle fleet. A dedicated development programme could lead to the maiden launch of the Shuttle 2 in 2001.

No US plans for manned missions to the Moon or Mars can be realised without a solidly-established goal set in the 1990's. The low-intensity of current USA space policy will not lead to such projects, unless international cooperation is well established early in the development phase.



In the coming decade large space structures will be built in orbit. This spectacular picture from Space Shuttle mission 61B shows the construction of the ACCESS tower by Jerry Ross, who is anchored by a foot restraint to the manipulator arm which is controlled from inside Atlantis by Mary Cleave.

Ariane Evolves

Arianespace, operator of the European-built Ariane rocket, has scheduled the new Ariane 4 for its maiden launch in 1988. Despite the failure of Ariane V18 in May 1986, the Ariane family has made an impressive dent in the commercial market.

Heavy-lift launch vehicles: 1990-2001.

			Payload
Soviet Union			
D-1 CIVILIAN PROTON	(1965)	18	40,000 LEO
D-1 MILITARY PROTON	(1967)	22.5	50,000 LEO
SLV-16	(1986)	13.5	30,000 LEO
ENERGIA	(1987)	100	220,000 LEO
ENERGIA 3-STAGE	(under study)	148	330,000 LEO
SPACE SHUTTLE	(1990)	29.7	66,000 LEO
United States			
TITAL 3 COMMERCIAL	(1964)	12.42	27,600 LEO
SPACE SHUTTLE	(1981)	27.	50,000 TO 60,000 LEO
TITAN 34D	(1982)	12.42	27,600 LEO/4,200 GEO
TITAN 4	(1988)	17.55	39,000 LEO/10,000 GEO
ADVANCED HLV	(1993)	67.5	100,000 TO 150,000 LEO
SHUTTLE 2	(2001)	18	20,000 TO 40,000 LEO
Europe			
ARIANE 5	(1995)	7.92	17,600 LEO
China			
LONG MARCH 2-4L	(1989)	9	20,000 LEO/5,400 GEO
Japan			
H-2	(1992)		4,400 GEO

The versatility of the Ariane 4 will continue to give Europe a competitive edge through the early 1990's. The March 1986 addition of a second Ariane launch pad enables Arianespace to launch as many as 12 flights per year, although present market forecasts call for about eight annual launches in the early 1990's.

With the backlog of US launches, Arianespace has had no problem in finding customers for Ariane 4, which has a payload capability of up to 9,250 pounds. It has six configurations to meet varying launch needs and will replace the Ariane 2 and 3 launch vehicles by 1990.

France is also evaluating a Super Ariane 4 concept, able to lift 1500 pounds more, that will be used as an interim vehicle before the launch of Ariane 5. The Ariane 5 will be able to lift up to 17,600 pounds and will be launched no sooner than 1995.

At about the same time, ESA's Columbus module will be under final preparation for launch to the international space station on the space shuttle. The first module will be permanently attached to the station. Later, mantended free-flyers will be launched by the Ariane 5.

An extended stage for the Ariane 5 in under study for the boosting of presurised modules to the space station or to an independent European space station. Current disputes with the US

Defence Department has France advocating the development of an independent European space station.

Development of Columbus follows the basic concept of West Germany's Spacelab programme, which has been adversely affected by Challenger. Only one West German-dedicated Spacelab flight is scheduled for the next five years.

A European Manned Programme

Europe is approaching long-term cooperation with the US cautiously, at the same time planning the development of a manned programme of its own. Europe's first spacecraft could be the miniature spaceplane called Hermes. France committed itself to develop Hermes and ten ESA member nations joined the early stages of the programme in late 1986.

The original design of Hermes called for a 10,000 lb payload capability and a crew capacity of six. The latest Hermes design submitted following a safety review after the Challenger accident, incorporates an ejectable crew cabin that will hold three astronauts, a limited cargo capacity of 6,600 lb, a solid rocket extraction system and other major safety enhancements. The Hermes launch vehicle, Ariane 5, will also have safety modifications made before being man-rated.

France is discussing the docking of Hermes with both the US and Soviet space stations.

Considering possible delays in both the development of the Ariane 5 and Hermes, the first unmanned launch of the French spaceplane is unlikely to take place before 1998.

A 21st Century Launch Vehicle

Britain has been working on proof-of-concept studies for a re-usable, single-stage spaceplane called Hotol. A hybrid engine would use atmospheric oxygen to accelerate the craft through the atmosphere, and rocket propulsion in space. Hotol would both take-off and land on a runway.

West Germany has introduced its own concept of a post-Ariane 5 launcher, called Sanger. Sanger would use an air-breathing launcher the size of a 747 to lift a rocket-powered spaceplane into the upper atmosphere.

The Hotol and Sanger concepts could influence ESA's development of manned space flight in the 21st century.

European Astronauts

Selection of European astronauts has been dependent on international agreements with the US and with the Soviet Union.

The first group of four European astronauts was selected in 1977 for the Spacelab 1 flight. Two of the men were later selected for NASA astronaut training. But France was able to put the first west European in space onboard a Soviet Soyuz-T mission in 1982. That same man, Jean-Loup Chretien, will fly to Mir in 1988.

Two West Germans and one Dutchman flew on the Spacelab D-1 flight, and another Frenchman flew on a later shuttle mission. Britain also selected four astronauts to serve as payload specialists on shuttle flights, but new NASA policy has indefinitely delayed the prospect of the first UK citizen in space.

West Germany postponed selection of six astronaut-trainees for the Spacelab D-2 flight and has now decided to limit the number to three or four, with the launch delayed to 1992.

During the 1990's astronauts will be selected to fly the Hermes spaceplane. Initial Hermes crews will probably be French but later missions will include other Europeans.

China Moves Into International Market

The problems of the last 18 months in the US and European space programmes have given the People's Republic of China the opportunity to offer launch services and the drive to develop a more independent programme.

Prior to the Challenger accident, China began offering commercial launch services with its Long March rocket family. The largest, Long March 3, is capable of launching over 3000 lb to geosynchronous orbit. It was first launched in early 1984 from a new launch centre at Xichang.

The Long March 2 is also a Titan-class rocket with the ability of lifting 5000 lb to low-Earth orbit. By uprating the three-member rocket family China hopes to secure a good portion of the commercial market in the 1990's.

Though China at present only averages two launches per year, it is demonstrating the reliability of the Long March rockets, which use rudimentary technology.

In late 1986, China defined four versions of the Long March 2 for potential launching of international satellites backlogged on Shuttle and Ariane manifests. China and Japan are both studying concepts for launching two to four small payloads at a time.

Development For The 1990's

One of the four Long March 2 derivatives has the lifting power of a Saturn 1B for low orbit and similar capabilities to the Ariane 3 and 4 for geosynchronous orbit. This version, using strap-on boosters, will be ready for commercial use in 1990.

Participation in the international space station will give China the opportunity to obtain new technology for their programmes leading into the 21st century.

China has re-established its interest in manned space flight and plans to use the US space shuttle to launch the first Chinese astronauts. By 2001, China proposes an independent programme involving a Gemini-class spacecraft and, later, a small space station.

Japan Moves From US Technology

For Japan, the 1990's mean space advancement in leaps and bounds. No space programme will grow as quickly during the next decade.

Following earlier success with the N-1 and N-2 since the mid 1970's, Japan introduced the new H-1 booster in August 1986. Like the earlier boosters, the H-1 uses part US technology to lift 1200 pounds to geosynchronous orbit. However, Japan cannot use the H-1 for international services because of US trade restrictions. Japan plans seven more H-1 launches in the next five years.

A heavy-lift launcher using all-Japanese technology will be first flown in 1992. This is the H-2 which will be capable of lifting 4400 lb to geosynchronous orbit, making it more powerful than the Titan-34D.

Japan is expanding launch facilities on Tanegashima Island to launch the H-2, which will be used for re-supply missions to the International Space Station.

Japan's Manned Space Goals

Japan has completed a mock-up of a space station module due to be launched by the US shuttle in 1995. An experiment platform will also be docked to the space station via shuttle or H-2. A remote arm is also being developed for the module.

Despite controversy with the US defence plans on the space station, Japan still intends to put Japanese astronauts in space through the US programme. Three astronauts have been selected for training for the Japanese Spacelab mission and one will participate on the 1991 flight.

Japan is also studying an unmanned mini-shuttle concept called Hope. Like Hermes, Hope will be launched on an expendable rocket, the H-2. First launch of the unmanned spacecraft is set for 1993 and subsequently Hope will serve as a mini-spacelab and a cargo ship capable of lifting 6,600 lb.

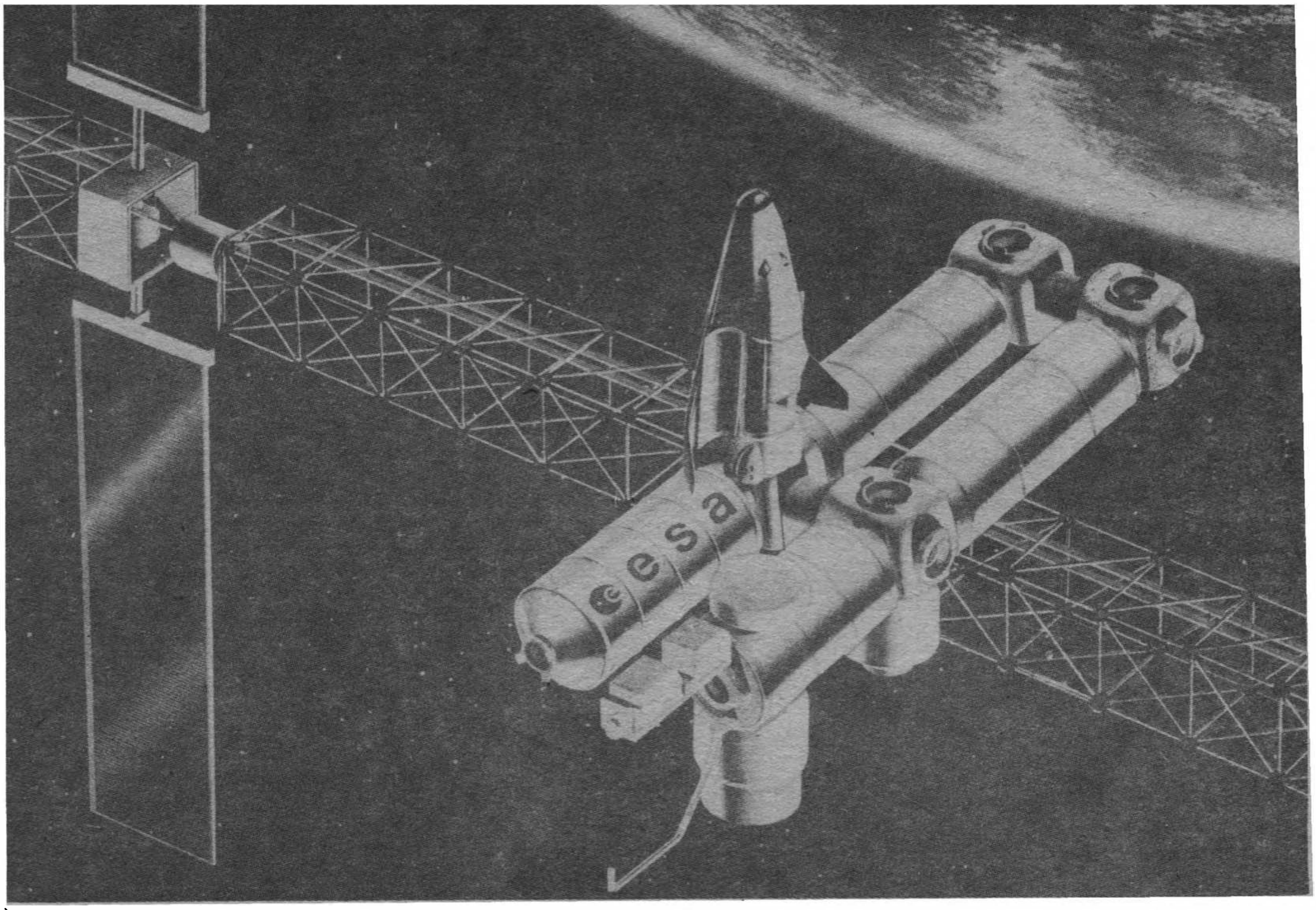
The second phase of the spaceplane project is the development of a hybrid air-breathing and rocket powered engine for manned use. The larger spaceplane will take off and land on a runway and development will be well advanced by 2001.

India's Domestic Programmes

India is trying to meet its own needs by launching domestic satellites on all-solid stage rockets. The launch rate is less than one per year, and a recent failure may delay the next launch.

In March 1987, the first launch of the Augmented Satellite Launch Vehicle (ASLV) failed. The ASLV uses the SLV-3 rocket plus two solid strap-on rockets to launch 330 lb. A polar satellite launch vehicle (PSLV) is also being developed.

India has been assisted by the US,



The Hermes space plane has been proposed by France to its European partners in ESA. With adequate flexibility in design it could adapt to developments in space exploitation up to year 2010 and complement ESA's Columbus space station programme. Hermes is here shown in one of its possible roles – that of supplying services to the international space station as a whole.
CNES

Soviet and European space programmes in the past and international cooperation will continue. An Indian cosmonaut flew to the Salyut 7 space station in 1984 and Indian payload specialists were training for a US shuttle mission prior to the Challenger accident.

Canada's Growing Space Industry

Canada's contribution to the International Space Station is a major one. Its Mobile Servicing Structure will be used during the construction and servicing of the station and will assist space shuttle and payload docking to the station modules. Modern robotics will be used in the structure and it will feature a heavy remote manipulator arm. The servicing structure will also be used to make repairs to the station and satellites.

Like Europe and Japan, Canada is not sure of the extent of its participation in the International Space Station. Canada has stated it is prepared to drop out of the project if controversy with the US Defense Department does not clear up.

Canada has patiently redesigned the service structure as station plans evolved and the new Canadian Space Agency is ready to find users for station space.

Canada uses US and European launch vehicles for satellite programmes and this will continue through the 1990's. The Canadian Astronaut Programme also relies on the US space shuttle and may extend to Hermes by 2001.

Six Canadian astronauts are training for shuttle missions, one flew on the shuttle in 1984. Like other possible payload specialists, the Canadians must wait until after the resumption of shuttle flights, before NASA passenger policy is established.

Intercosmos In Eastern Europe

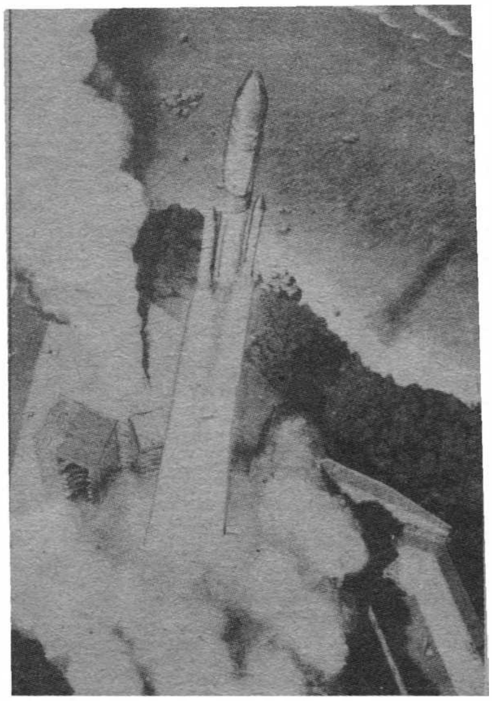
Eastern European countries have had the opportunity to fly cosmonauts to earlier Soviet space stations and that offer is being renewed for missions to Mir. A Bulgarian, to be launched to Mir in 1988, will be followed by other Warsaw Pact cosmonauts.

The Soviet Intercosmos programme has also launched men from North Korea, Mongolia, Vietnam, Cuba and Syria. None of these countries have established independent space programmes and will continue cooperation with the Soviet Union.

Looking To The Future

As year 2001 approaches, the US and Soviet space programmes will probably exhibit similar capabilities for the first time since the 1960's. The European and Japanese programmes will also probably be comparable by 2001. Where the programmes are likely to differ will be in their established goals for the early 21st century.

The Soviet Union has always established goals and then followed them through slowly and surely. The US has never been so dedicated to long-term plans. It is dedication which will put man back on the Moon and forward to Mars. International cooperation is essential for accomplishing such goals.



An artist's impression of the launch of Japan's H-2 rocket which is being developed by NASDA to serve as its main workhorse in the 1990's.

1957 FLASHBACK

30 Years of Space Exploration. . .

October 4, 1987 marks the 30th anniversary of the launch of Sputnik I, the Earth's first artificial satellite – an event which literally resounded round the world as the satellite's radio transmitter sent out its 'bleep, bleep ... '. Is it now possible to recapture the excitement of those early days and of the many subsequent 'firsts' of the Space Age?

***Spaceflight* magazine has been reporting space news, views and developments since its first issue in 1956. A careful selection of this material has now been brought together in the following 26 page special feature. In 30 years of space exploration we have seen the emergence of new technologies, new scientific discoveries and man's first steps into the harsh and ultimate environment of space. The story unfolds with the launch of Sputnik I . . .**

The Space Age is Here

By MAURICE ALLWARD

"The Space Age is Here." This was how one national daily newspaper headlined the news of the Russian satellite, and few readers of *Spaceflight* will have disagreed.

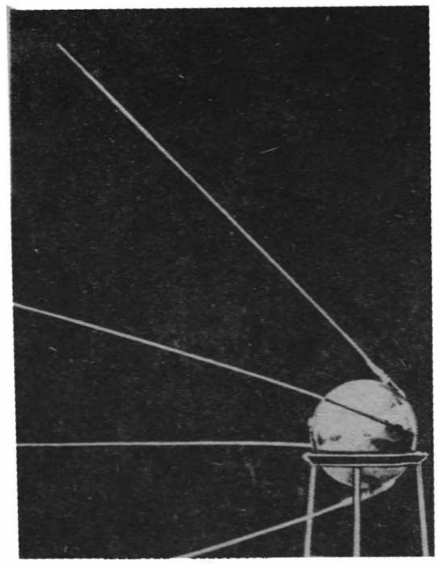
Admittedly, Ziolkovsky's historic paper on the subject of rocket motion of 1903, Goddard's liquid-fuel rocket of 1926, the German V2 and, more recently, the Aerobee and Viking high altitude research rockets, have all, in turn, been hailed as the "first steps" to interplanetary flight. But the Sputnik (meaning "fellow-traveller"), as the Russians called their satellite, was different. For years articles have been appearing at an ever-increasing rate on space travel. And, as the pattern of development slowly evolved, it became clear that the first rung in the technological ladder to the planets would, indeed, be the construction of a vehicle capable of attaining a stable orbit around our planet.

In his paper "The Artificial Satellite", read at the Second International Congress of Astronautics, London, 1951, L. R. Shepherd, then Technical Director of the B.I.S., stated: "The uses to which a satellite vehicle might be put are sufficiently numerous to justify considerable expenditure on their development. Their value as scientific research stations would be beyond measure." He continued: "*But the real value of the orbital vehicle lies in its importance as an essential springboard in the supreme adventure of interplanetary flight. This without doubt must be regarded as the main reason for our interest in the device, all other purposes being of secondary importance.*"

At the same Congress it was revealed that "one government had already announced its intention of pursuing the development of the satellite vehicle". This was confirmed in July 1955, when it was announced in Washington that the United States intended to establish small, unmanned, artificial satellites in space as a contribution to the International Geophysical Year.

From then onwards, the establishment of a satellite was obviously only a matter of time. Anticipation of the event could, therefore, have reasonably been expected by the world in general and by interested parties, such as the members of societies such as our own, in particular.

As it was, the historic announcement from Moscow on October 5 that "As a result of intense, large-scale research conducted by Soviet research institutes and design organizations, the world's first artificial earth satellite has been developed in the Soviet Union. On October 4, 1957, the first satellite was successfully launched from the U.S.S.R.", astonished everybody—some members of the B.I.S. in particular!



This is it! The first official picture of the Russian satellite, which the Russians call "Sputnik". It is seen here on a stand, some time before it was launched into outer space to whirl round the Earth at a speed of 5 miles per second

Without doubt the reason for this was not so much that a satellite had been launched, but that it had been launched south from Russia over Moscow, instead of south-east from Florida over the Atlantic! True, Professor Leonid Sedov had announced at the sixth International Congress, in Copenhagen in 1955, that the Soviet Union intended to launch satellites during the Geophysical Year. But, in spite of K. W. Gatland's reminder in the July 1957 *Spaceflight*, the writer confesses that, faced with the wealth of information released on the U.S. Vanguard project, he tended to overlook this, as probably did most other people west of the Iron Curtain.

After taking in the bare fact of the announcement, the Press was eagerly perused for further details. Then came a surprise almost as great as that of the satellite itself: its reported weight. The figures quoted varied from various sources, but averaged around 180 lb. At first the present writer was convinced that a decimal

This diagram of a model of the satellite which the Russians have launched into space, was recently published in the Soviet "Technology for Youth". Translations of Russian annotations are as follows, reading from top to bottom: Magnetometer; Mercury accumulator; Radio transmitter; Spring for detaching satellite from rocket, Explosive pin and rocket nose; the small diagram on the left shows the orbits of the artificial satellite, while the bottom diagram illustrates positions of the satellite in relation to the Earth (left to right) Night—invisible; Evening and morning—visible; Day—invisible

By courtesy of the United Press

point had got lost somewhere, but soon it became clear that the satellite did, in fact, weigh 184·3 lb. This is some nine times as great as the proposed Vanguard satellites and, remembering the latter's approximate 1,000-to-1 ratio of the launching-to-satellite weight, it became apparent that the Russian launching vehicle must have been an impressive monster weighing around 100 tons. This was confirmed by Moscow, who announced that it was a three-stage vehicle powered by a first-stage motor delivering 264,000 lb. thrust and burning out at about 4,500 m.p.h. The second stage incorporated a 79,000-lb. motor burning out at something over 12,000 m.p.h., and the third had a relatively small motor, designed to give the tangential push required to establish the satellite in its orbit.

The Sputnik was thus very much bigger than most space-travel enthusiasts had thought practicable for this important first step towards interplanetary flight. Most recent design studies had, primarily on the grounds of economy, been concerned with the smallest possible orbital vehicle. America's Vanguard itself is expressly designed to the minimum size that can reasonably be expected to establish an instrumented satellite.

Although the satellite was fitted with a comparatively simple radio transmitter, the payload was obviously sufficient to allow complex instrumentation in later vehicles and, perhaps, the carriage of animals or a television camera.

The next big surprise regarding the Sputnik concerned its orbit. The first point to note was that, lying some 65 degrees off the equator, little or no assistance will have been attained from the rotation of the Earth. In the case of the proposed orbit of the Vanguard (20 degrees to the equator) this bit of "free speed" is estimated to be worth about 900 m.p.h. With the Vanguard the Americans are hoping for an orbit with 200 and 800 miles as its upper and lower limits; to achieve even these limits extremely close control will be required over the burnout speed of the satellite and its final positioning in relation to the surface of the Earth. According to the circular issued by the British Astronomical Association on October 15 (Circular No. 390), the height of the Sputnik seemed to vary between 603 miles and 118 miles, indicating either a "fluky" first attempt or else exceptionally well-developed control techniques. That the former was, perhaps, incorrect was indicated by an announcement from Moscow, at 12.15 G.M.T. on October 5, including the following details of the orbit:

"At 12.04 Moscow time the satellite's position was in the area of the city of Johannesburg. Since the moment of its passage over the Moscow area at 01.46 on October 5, it has circled the Earth about 6½ times. The period of its orbit round the world, according to precise assessment, lasts 96·2 minutes. The radio transmitters are working uninterruptedly . . . The appearance of the satellite is expected to-day in the areas of the following cities (Moscow time): Detroit, 16.30; Washington, 16.31; Magadan, 17.52; Calcutta, 19.16; Ulan Bator, 19.23; Karachi, 20.54; Alma Ata, 20.58; Baghdad, 22.32. On October 6: Yakutsk, 00.25; Prague, 01.49; Riga, 01.51; Moscow, 01.52; Oslo, 03.27; Rangoon, 05.28; Bandoeng, 05.35; Leningrad, 06.49; Moscow, 06.50; Bombay, 07.03; Damascus, 08.34; Manchester, 10.05; Paris, 10.06; Rome, 10.09."

Such precise times meant that either the Russians had an extremely efficient orbital computer available—or that so confident were they of the control techniques that they had worked out the times *before* the launching. This latter suggestion seems only slightly less incredible than the former. Whichever was the truth, it was obvious that the world was witnessing one of the most spectacular scientific advances to date. The "bleeps" from space told the world that Russia's satellite programme, nôt America's, was the vanguard; but before long, it is certain that more satellites will be sent up from both East and West.

Milestones

1957 Launch of Sputnik 1, first artificial satellite, October 4.

1958 Explorer 1, first US satellite launched (discovers Van Allen radiation belts), January 31.
Inauguration of NASA, October 1.

1959 Launch of Luna 2, first man-made object to hit the Moon, September 12.

1960 Launch of Tiros 1, first meteorological satellite, April 1.
Launch of Transit 1b, first navigation satellite, April 13.
Launch of Midas 2, first infrared surveillance satellite, May 24.
Launch of Echo 1, first passive communications satellite, August 11.
Launch of Courier 1b, first active communications satellite, October 4.

1961 Yuri Gagarin becomes first man in space, April 12.
American intent to land a man on the Moon 'before this decade is out' declared by President Kennedy, May 25.

1962 First American orbital flight made by John Glenn, February 20.
Launch of Telstar, first commercial communications satellite, July 10.

Valentina Tereshkova

1963 First woman in space, Valentina Tereshkova, June 16.
Launch of Syncom II, first geosynchronous communications satellite, July 26.

1965 First spacewalk by Leonov, from Voshkod 2, launched on March 18.
Launch of Early Bird (Intelsat 1) first commercial geostationary communications satellite, April 6.
First views from space of another planet: Mariner IV flyby of Mars, July 14.

1966 First pictures from Moon's surface sent back by Luna 9, January 31.
First docking in space by Gemini 8 and Agena target, March 16.

1967 First Saturn V flight, November 9.

1968 Launch of Apollo 8, first manned flight around Moon, December 21.

1969 Launch of Intelsat 3F-4 completes global satellite communications network, May 21.
Astronauts land on the Moon, Apollo 11, July 20.

1970 Return of Luna 16 first unmanned sample-and-return Moon mission, September 24.
Launch of Luna 17 with Lunakhod Moon Rover, November 10.

1971 Salyut-1 orbiting manned laboratory launched by Russians, April 19.

1972 Approval to develop Space Shuttle announced by President Nixon, January 5.
Launch of ERTS-1 (Landsat 1) first Earth resources technology satellite, July 23.

1973 Launch of Skylab, American orbiting manned laboratory May 14.
Pioneer 10 reached Jupiter, December 3.

1974 End of final Skylab mission (Skylab 3). Endurance record 2017 hours 15 minutes, February 8.

1975 European Space Agency set up, May 30.
Apollo-Soyuz joint US/USSR space mission July 15-24.
First pictures from the surface of another planet sent back by Venera (Venus) 9, October 22.

Explorer

On January 31, 1958 the United States Army successfully launched America's first satellite, called Explorer. Using a modified Jupiter-C rocket, a 30.8 lb baby "moon" was placed in orbit on the first attempt. The elliptical orbit, 200 to 1,800 miles, was so well established that scientists predict it is possible for the satellite to remain in orbit between two and 10 years. It is circling the Earth in a 114.6 minute cycle.

The launching vehicle itself was a 69 ft long missile consisting of four stages. The first stage contained a liquid-propellant rocket engine. Stage II consisted of eleven solid-propellant rockets clustered in a circle with three Stage III solid propellant rockets mounted inside the Stage II cluster. The fourth stage carried the satellite with one solid-propellant rocket as the propulsion unit. The satellite and Stage IV rocket were designed to remain as one unit and the unit was not designed to be recovered.

The satellite itself consists of the instrument-carrying forward section of the cylindrical shell-casing and the fourth-stage rocket motor which is attached to the instrument carrier. The satellite is about 80 in long and 6 in in diameter. The electronic payload weighs about 11 lb, exclusive of the casing. Instrumentation and telemetry in the satellite are designed to gather and transmit four types of information: external skin temperature, internal temperature, cosmic dust erosion and cosmic ray data. The main part of the instrumentation package is a cosmic radiation experiment originally designed by Dr. James Van Allen of the State University of Iowa. The major element of this experiment is a Geiger-Müller counter. Dr. Van Allen's scientific experiment in the satellite is concerned with the measurement of the rate and intensity of cosmic rays as they occur above the atmosphere of the Earth.

The average counting rate expected will produce approximately 32 pulses per second, which will cause a frequency change once each second. On this basis, the system is capable of transmitting cosmic ray information at 40 times the normal rate if such activity occurs during intense solar or magnetic storms.

In addition to the information received directly from the satellite through its instruments, the vehicle also can provide basic scientific information simply by being in orbit.

Ground observations of the orbiting satellite will provide information about the ionosphere, geomagnetic field intensity and atmospheric density – information that up to now has been arrived at by calculations based on indirect evidence. Accurate optical and radio observation of changes in the satellite orbit may provide information as to gravitational anomalies in the Earth.

Spaceflight, April 1958

Lunik II Hits the Moon

The second Soviet space rocket, launched on September 12, reached the Moon [September 14] at 2 min. 24 sec. past 10 (past midnight, Moscow time) to make history with the first space flight ever made from the Earth to another celestial body.

The space vehicle was a multi-staged rocket, whose last stage was a guided rocket weighing 1,511 kg (about 1½ ton).

Scientific instruments, with container and power supply, weighed 309.2 kg (over 869 lb).

A *Tass* announcement said the programme of scientific observations had been completed. The radio transmitters in the container with the scientific and measuring equipment ceased functioning at the moment it hit the Moon.

Pennants with the arms of the Soviet Union and the inscription, "The Union of Soviet Socialist Republics, September, 1959," were carried by the rocket, and measures had been taken to ensure that the pennants remained intact when the rocket hit the Moon.

Measures were also taken to prevent the lunar surface from being contaminated with terrestrial bacteria.

"The Soviet space rocket's flight to the Moon is an outstanding achievement of science and engineering," says the announcement. "A new page has been turned in the exploration of outer space."

The rocket sent back information about the Earth's radiation bands and magnetic field, cosmic rays, micro-meteorites and interplanetary gas. Radio measurements of the distances and angles determining the rocket's position and measurements of radial speeds were used to establish with precision the trajectory of the rocket's flight.

These observations and computations showed that it was following a trajectory very close to the one projected.

In addition to the main tracking stations, radio observations of the vehicle were conducted by a large number of amateur radio operators and radio centres in the Soviet Union and in European and Asian countries.

Speaking of the great weight of the rocket's last stage, which is 39 kg heavier than that of the first Soviet space rocket, Academician Topchiev, vice-president of the USSR Academy of Sciences, says that this is another big step forward. The Soviet scientists have been able to send into space much more scientific and technical instrumentation, making it possible to carry out more thorough studies of cosmic space en route to the Moon.

The programme of studies being carried out with the space rocket has been supplemented by measurements of the Earth's magnetic field at heights which have not been attained with artificial satellites, Professor Fyodorov says. The planned experiments may yield some quite unexpected results.

Now that man has successfully invaded the depths of cosmic space, goes on to say, broad international co-operation in this field becomes especially important. The United States and the Soviet Union lead the world in space exploration. It is to be hoped that as a result of the exchange of visits between Khruschev and Eisenhower, relations between the two countries will improve to an extent such as will make it possible to have closer ties between Soviet and American scientists.

Spaceflight, October 1959

Two Major Triumphs

Two important events in astronautical science have taken place since the last issue of ***Spaceflight*** appeared. One is the outstanding success of the 98.4 lb American solar-probe, Pioneer V, in signalling back to Earth information on conditions in space over millions of miles. With this must be linked the use of Jodrell Bank's radio-telescope in long-range space-communications. The other is the considerable Russian triumph in putting into orbit close to the Earth a fully-equipped embryo "space-ship" of 10,010 lb, complete with a 2½ ton detachable pressurised cabin, dummy astronaut and oxygen equipment.

Both experiments are remarkable in their own right. The first has shown the extent to which use can be made of small payloads by ingeniously-designed miniaturised equipment; the second how the development of large rocket boosters is leading to the early arrival of man in space.

However, no one is likely to suggest that success with the latter will be achieved overnight. An orientation fault deprived Soviet scientists of claiming full success for their experiment (similar troubles have afflicted the American Discoverer programme aimed at the recovery from orbit of a 300 lb capsule), while the Russians, at least, apparently still consider re-entry into the atmosphere a difficult problem. The Americans, of course, have their own plans for orbiting a man next year in the much smaller one-ton Mercury space-capsule.

Spaceflight, July 1960

Triumph of Sputnik V

Another milestone in astronautics has been reached by the Russians. On August 19, it is believed from Aralsk, near the Aral Sea, a multi-stage rocket was launched carrying a payload of over 4½ tons in the shape of a two-part spacecraft which entered a near-circular orbit with an apogee of about 210 miles and a perigee of some 190 miles. The vehicle contained a varied "cargo" comprising two dogs, 40 mice and two rats, fruit flies, plants and fungi, microscopic water plants and some seeds. There were also instruments for measuring light and heavy nuclei in primary cosmic rays, ultra-violet radiation from the Sun and the amount of cosmic radiation in the pressurised animal container.

Inside the spacecraft, television was used for the first time to observe the reactions of the test-animals in orbit.

The climax to this remarkable experiment came more than 24 hours later when, on a command signal from the ground, a retro-rocket fired to slow down the spacecraft and cause it to re-enter the atmosphere. At this

Milestones

1976 Viking 1 and 2 soft-landers land on Mars, on July 20 and September 3.

1977 Launch of Russian Salyut 6 orbiting manned laboratory, September 29.

1979 Closest approach to Saturn by Pioneer 11, September 1.
First launch of European Space Agency Ariane Satellite Launch Vehicle, December 24.

1980 Pictures of Saturn and its moons sent back by Voyager 1.

1981 First flight of Space Shuttle Columbia, April 12.

1982 Space Shuttle launches its first commercial payload on STS-5 mission, November 11.

1983 First flight of European Space Agency Spacelab manned orbiting laboratory, aboard Space Shuttle orbiter Columbia, November 28.

1984 President Reagan announces American permanently manned Space Station development, January 25.
First satellite repair in space: Solar Max satellite, Shuttle mission 41C, April 10-12.
First commercial Ariane launch (V9) by Arianespace, May 22.
Svetlana Savitskaya becomes first woman to spacewalk, from Salyut 7 space station, July 25.
Salyut 7 endurance record of 237 days set by Kizim, Solovyov, Atkov, October 2.
Kathryn Sullivan becomes first American woman to spacewalk, Shuttle mission 41G, October 11.
First space salvage operation: Shuttle orbiter Discovery lands with Westar, Palapa satellites retrieved from space after launch failure in February, during 14th Shuttle mission, November 8-16.

1985 Soviet Vega 1 capsule lands on Venus (June 11) followed by Vega 2 four days later.
Giotto, Europe's Halley probe, launched by Ariane on July 2.
American ICE probe passed behind coma of Comet Giacobini-Zinner, in the first ever cometary approach, on September 11.
Space Shuttle Challenger carries a record crew of eight on German Spacelab D1 mission launched on October 30.
Roy Gibson appointed as first Director-General of British National Space Centre on November 20.
First termination of space mission due to crew illness when Soviets return Salyut 7 crew to Earth on November 21.

1986 Voyager 2 space probe flies by Uranus and sends back pictures to Earth, January 24.
25th Shuttle flight ends in disaster when Challenger explodes, killing all seven of its crew, which includes first civilian in space. Shuttle programme halted January 28.
Russia launches Mir (Peace), first module of a permanently manned space station, February 20.
Soviet Vega 1 probe closest approach to Comet Halley nucleus (9,000 km) on March 6. Vega 2 fly-by three days later.
European Space Agency Giotto space probe photographs nucleus of Halley's comet, March 13.

1987 Japan's Astro-C satellite was launched on Feburary 5 placing the largest ever satellite-borne x-ray detector in orbit.
Japan launches its first Earth resources satellite, MOS-1, on Feburary 19.
Soviet astrophysics module Kvant docked at second attempt with Mir space station on April 9.
First launch of new Soviet heavy lift booster Energia on May 15.

point, the vehicle was on its 18th orbit and had travelled nearly 500,000 miles. *Tass* reported that the spacecraft "was provided with a special thermal shield and passed safely through the Earth's atmosphere". It was also said that the bio-capsule was catapulted clear of the spacecraft as a safety measure after re-entry and that both made successful landings some 6¼ miles from the designated point in an undisclosed region of the USSR.

Although it will be some time before all the results of this historic experiment have been analysed, the next step of substituting a man, or possibly two men, for the animals cannot be too far away.

Spaceflight October 1960

Echo I Encounters Darkness

Echo I began to encounter brief periods of darkness for the first time on August 23. The communications satellite went into the Earth's shadow for about 2 minutes as it passed over Southern California at 5.25 am (Wed.) EDT. Since then the periods of darkness have been increasing with each orbit, reaching a maximum in December when Echo was in the Earth's shadow some 30 minutes during each 118 min. transit. Thereafter, the periods of darkness will diminish for the next three months.

The National Aeronautics and Space Administration issued special alerts to optical, radio and radar tracking facilities around the World urging maximum observation as Echo enters and emerges from periods of darkness. The purpose of this close observation is to try to maintain a precise determination of the orbit.

Since Echo was launched on August 12, hundreds of experiments have been conducted, using the satellite as a passive relay for radio signals. These transmissions included teletype signals, facsimile photographs, two-way telephone conversations using commercial equipment, trans-continental and trans-Atlantic signal relays and experiments to determine the effects of the ionosphere on radio signals.

While the Echo balloon satellite is the largest object yet placed in orbit around the Earth, its launching also established other "firsts" in missile technology. For example, its precise, near-circular orbit, was achieved with the help of a 42 lb electronic device developed especially for Delta space vehicles to NASA specification. Called a flight controller, the device is designed to inject the satellite into a precise orbit that will vary no more than 100 miles between the highest and lowest points at its planned 1000-nautical-mile altitude above the Earth.

Spaceflight January 1961

European Co-operation in Space

At a meeting of the Council of Europe in Strasbourg on September 21, Mr. David Price, MP presented a comprehensive report on "European Co-operation in Space Research and Technology." In an introduction, the author acknowledges extensive assistance from the British Interplanetary Society.

The document placed before the Committee of Ministers the following recommendations:

(1) That they study as a matter of urgent policy the possibilities and cost of setting up a European agency to undertake a space programme, based upon a space vehicle developed and built in Europe, and to promote the peaceful uses of outer space.

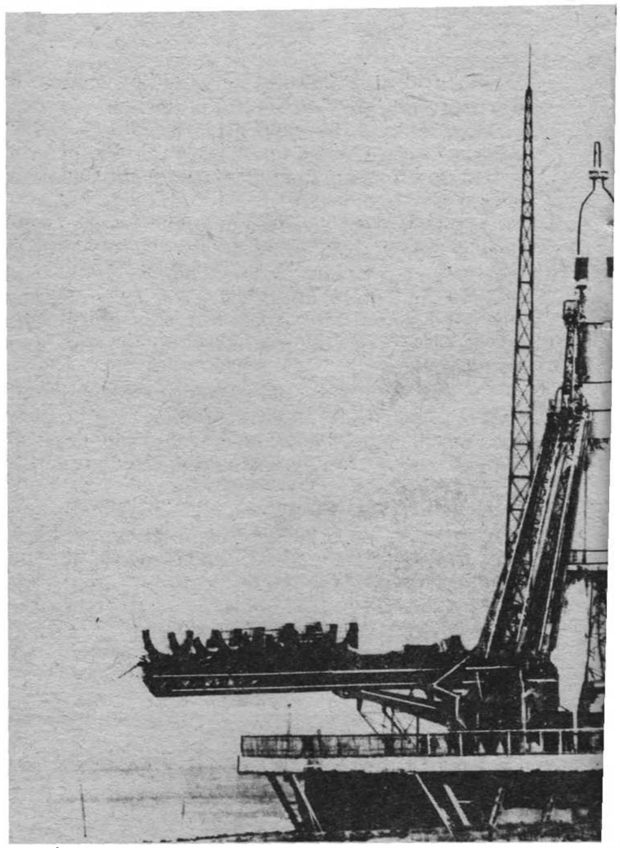
(2) That they ascertain which member States would be willing in principle to take part in a European programme of space research and the limit of the financial and scientific commitment which each participating State would be willing to undertake.

(3) That, if warranted by these studies and investigations, they prepare a specific plan for the creation of a European space agency and submit it to member-Governments for early ratification.

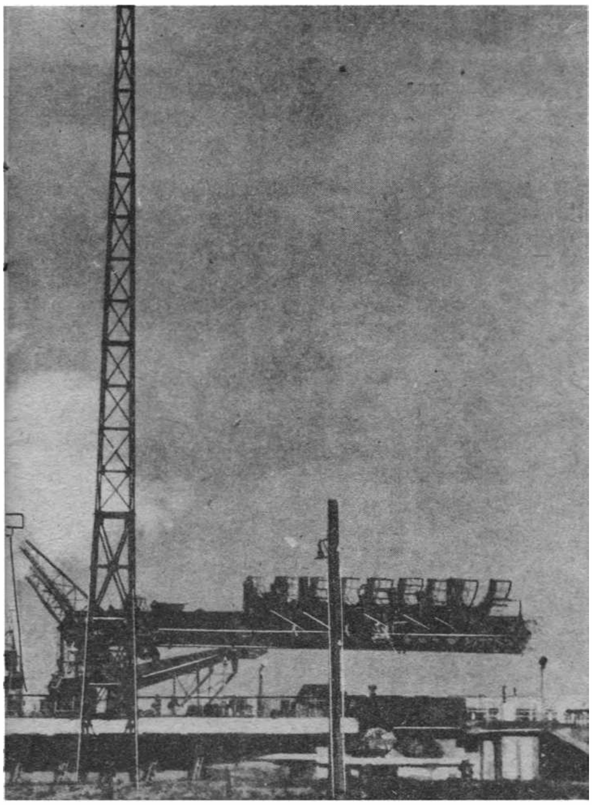
(4) That any European space agency which they may create should be subject to overall control by a committee of the appropriate Ministers and to the parliamentary influence of this Assembly.

(5) That they keep this assembly informed of the progress made and that this Assembly be consulted as to the future development of this programme.

After surveying the motives for space research, the types of vehicles



Lift-off of a Soviet launcher, the only man-rated vehicle in the Soviet launch vehicle inventory. The latest Soyuz mission to Mir used essentially the same vehicle configuration as the Vostok used to put Yuri Gagarin in orbit in 1961.



The original seven US astronauts in front of an F-102. They are (from left): M. Scott Carpenter, L. Gordon Cooper, John H Glenn, Virgil I. Grissom, Walter M Schirra, Alan B Shepard and Donald K. Slayton.

required and their method of propulsion, Mr. Price outlines the probable technical and economic benefits of space research and technology placing special emphasis on satellites for communication, navigation and meteorology. He next turns to political and legal problems, Russian and American achievements and prospects, and the British space programme.

The present British space programme, Mr. Price points out, is easily the largest currently undertaken by any European country. It may be divided into six categories: (i) upper atmosphere research with sounding rockets; (ii) tracking, both optical and by radio, of satellites and space probes; (iii) World Data Centre "C" and satellite prediction service; (iv) the design of instruments for satellites; (v) joint venture with the United States for the launching of British instrumented satellites by an American space vehicle; and (vi) design studies for the adaptation of British military rockets for space research, and for satellites which they could carry.

Spaceflight, January 1961

Man Into Space

The Russians cannot now be far from making an attempt to place their first astronaut in close-orbit around the Earth. At the time of writing, five experimental launchings have been made with 4½ ton spacecraft, the latest on March 25 when the dog Zvesdochka (Little Star) was safely recovered "at a predetermined point in the USSR".

A change in the pattern of the experiments was evident in the launching on March 9 this year when the spacecraft was commanded to return after spending a much shorter time in orbit. On this occasion, only one dog was carried with the usual complement of smaller test animals, insects, etc., and all were safely recovered. The fifth experiment on March 25 repeated this procedure – again with success.

Meanwhile, in the United States, sub-orbital ballistic tests of the one-ton Mercury capsule are working up to the stage where one of the three astronauts selected may be given the opportunity of becoming a passenger in a Redstone-boosted capsule.

Spaceflight, May 1961

Mission to Venus

On February 12 the Russians launched an "automatic interplanetary station" on a transfer orbit to the planet Venus. Although radio communication was lost after about 15 days, the experiment is a clear foretaste of further probing missions in store – to Venus and Mars.

The space rocket took off from the sputnik at a precomputed point on its orbit. When this rocket had attained a velocity that was 661 m/sec more than the escape velocity and the rocket had reached a precomputed point in space, the rocket engine stopped and the automatic interplanetary station separated from the rocket to start coasting towards Venus. This was the first time a guided vehicle had ever been fired in an interplanetary orbit from a sputnik carrier.

Spaceflight, July 1961

First Man in Orbit

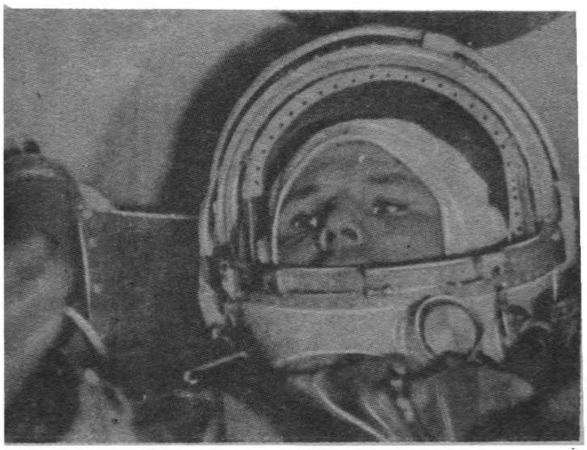
On April 12 a Soviet citizen, Major Yuri Gagarin, became the first man to orbit the Earth. His "Vostok" spacecraft landed safely in a prearranged area in the Soviet Union after a flight lasting one hour 48 minutes.

The world received the news that a man had been launched into space while the flight was actually in progress. These were the words of the *Tass* announcement as they were broadcast over Moscow Radio:

"The world's first satellite spaceship, the Vostok, with a man onboard, has been put into orbit round the Earth in the Soviet Union on April 12, 1961.

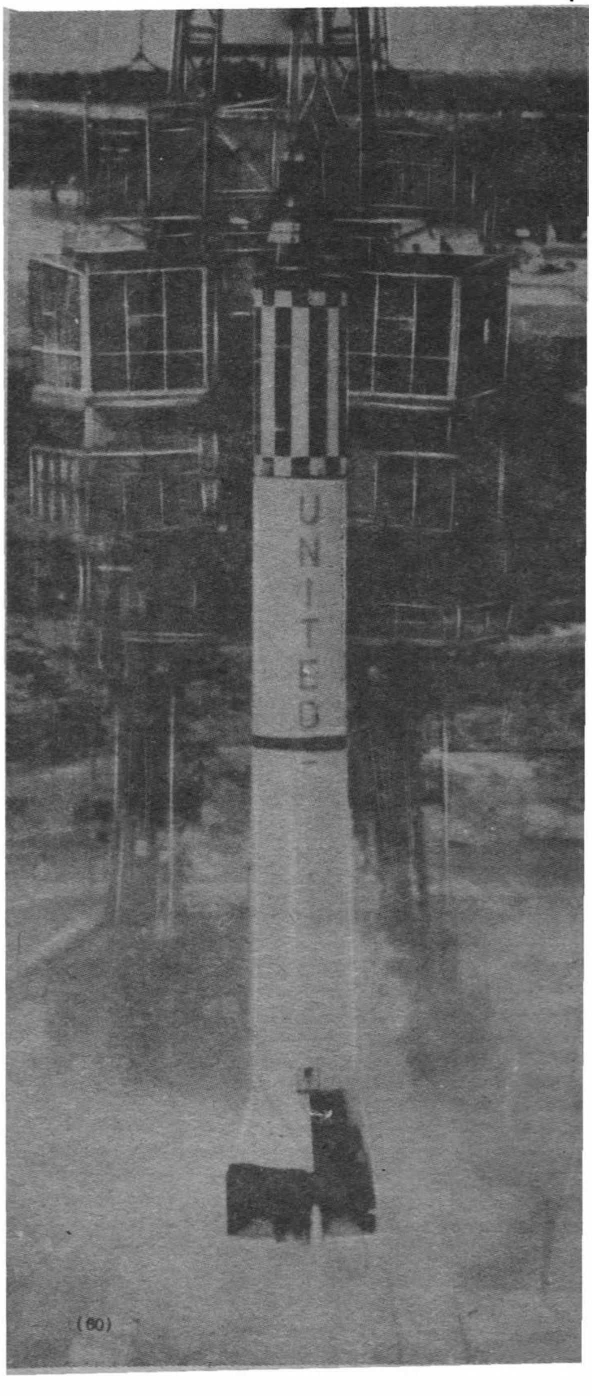
"The launching of the multi-stage space rocket was successful and after attaining the first escape velocity and the separation of the last stage of the carrier-rocket, the spaceship went into free flight on a round-the-Earth orbit.

"Two-way radio communication has been established and is being maintained with space navigator Gagarin. The frequencies of the short-wave transmitters on board are 9.019 and 20.006 Mc/sec., and in the



Yuri Gagarin became the first man in space after an epic 108-minute flight on April 12, 1961.

Alan Shepard begins his May 1961 15½ minute sub-orbital flight – the first American to reach space.



ultra-short-wave range 143.625 Mc/sec. The condition of the navigator in flight is being observed by means of radio telemetric and television systems."

According to reports received from the spaceship at 9.52 am (Moscow Time) – 7.52 am BST – Major Gagarin, while over South America, reported: "Flight is proceeding normally, I feel well."

At 10.15 am Major Gagarin reported from the Vostok that he was over Africa and was standing up well to weightlessness. Experts busy with the maps and radio equipment exchanged glances. Everything was fine, everything was going well.

The moment for landing was drawing nearer.

One after another, reports were coming in of new fixes of radio signals from the spaceship, which was already on the ground, and planes and helicopters were dispatched immediately to the spot. They were not needed, however. The telephone rang and a happy, excited voice reported:

"Gagarin is with us . . ."

The call came from a village not far from the landing point.

After landing, the astronaut had not waited for planes to come for him. Feeling fit, he had gone to meet the people who had rushed out to welcome him.

The flight was over.

Spaceflight July 1961

America's Space Triumph

An outstanding and well-merited achievement in the United States space-programme occurred on February 20, 1962, when Lt. Col. John Glenn successfully completed three orbits of the Earth in the Mercury capsule MA-6. The total flight time from lift-off to touch down was 4 hr. 56 min. Despite troubles with the automatic attitude control system, the astronaut kept the spacecraft under proper orientation using the manual-electric Fly-by-Wire system and he also operated the fully manual system which employs a separate system of attitude gas-jets with mechanical linkages. Total mass of the capsule in orbit was about 3,000 lb, which compares with 10,430 lb for the Soviet spacecraft Vostok II in which Major Gherman Titov made 17½ orbits of the Earth on August 6/7, 1961.

Spaceflight May 1962

Probing the Planets

On December 14 the spacecraft Mariner II was scheduled to pass the planet Venus at a distance of some 20,900 miles – a considerable triumph for NASA and the US space programme. Launched from Cape Canaveral on August 27, the flight path of the space probe had been modified eight days later on command when the vehicle was nearly 1.5 million miles from Earth.

With NASA's 446 lb spacecraft Mariner II still transmitting and making its close approach to Venus on December 14, Russia's 1,970 lb photographic probe is heading out to reach a rendezvous with Mars sometime between May and June. So far high success has accompanied both exploits.

Spaceflight January 1963

The Moon in Close-up . . .

Details of the lunar surface never before seen by human eyes were revealed in dramatic fashion when the JPL spacecraft Ranger 7 transmitted 4,316 pictures by television before hitting the Moon at 1325 hr GMT on July 31, 1964. Launched by an Atlas-Agena from Cape Kennedy three days before, the 806 lb spacecraft took 68 hr. 59 min. to reach its destination, travelling a computed distance of 228,522 miles. First of the high-quality pictures was obtained when the vehicle was some 1,120 miles from the Moon 16 min. 42 sec. before impact; it showed an area of approximately 180,000 sq. miles in the neighbourhood of the Sea of Clouds. This had about the same resolution as the best pictures obtainable by large telescopes on Earth.

Spaceflight, November 1964

Three Steps in Space

Seven frenzied days of space activity ended on March 24 with the Ranger 9 spacecraft coming down on target in the crater Alphonsus and securing 6,000 more pictures of the lunar surface. The day before Major Virgil Grissom and Lt. Cdr. John Young had performed a near-faultless three-orbit mission in their GT-3 Gemini spacecraft, proving the ability to make orbital manoeuvres by controlled rocket thrust.

Despite these considerable achievements, it was the Russians who stole the "show" on March 18/19 with the dramatic flight of Voskhod 2 in which the cosmonaut co-pilot Lt. Col. Alexei Leonov emerged from the craft in orbit to perform the first human experiments in space. The pictures of this operation, secured by an externally-mounted television camera, are among the most dramatic which human eyes can expect to see. Leonov, clad in a pressure-suit with pressure bottles strapped to his back and tethered by a line, was seen emerging from an airlock behind the pressure cabin, moving slowly to the end of the vehicle and launching himself gently into space. His easy movements about his centre of mass and the way he was able to control his motions by arm actions (and possibly rejected air from the suit) gave a hint that future extra-vehicular operations involving the assembly and refuelling of spacecraft in orbit might be less difficult than had been envisaged.

Meanwhile, the step of achieving a rendezvous between two orbiting spacecraft must now be high on the Soviet agenda. With characteristic regard for the spectacular, it is doubtful if they will miss the opportunity of exchanging cosmonaut co-pilots in space.

Spaceflight, May 1965

The Surface of Mars

On August 15 a brilliantly conducted experiment in space exploration reached its climax with the close approach of the NASA space probe Mariner 4 to the planet Mars.

Mariner 4 has revealed the scientifically startling fact that at least part of the Martian surface is covered with large craters. This is a profound fact which leads to far-reaching fundamental inferences concerning the evolutionary history of Mars and further enhances the uniqueness of Earth within the Solar System.

Spaceflight, November 1965

France in Orbit

On November 26, at Colomb-Bechar in the Sahara, France succeeded at the first attempt in launching a 93 lb test-satellite into an elliptical orbit ranging in altitude between 330 and 1125 miles.

The Government decided in April 1964, to build launch facilities for sounding rockets and satellite launch vehicles in French Guiana. French Guiana's location in the equatorial zone at 5.3 degrees north latitude makes it possible to fire toward the east, i.e., the Atlantic (with a firing angle between – 20 degrees and + 100 degrees) and therefore to make use of the Earth's eastward rotation.

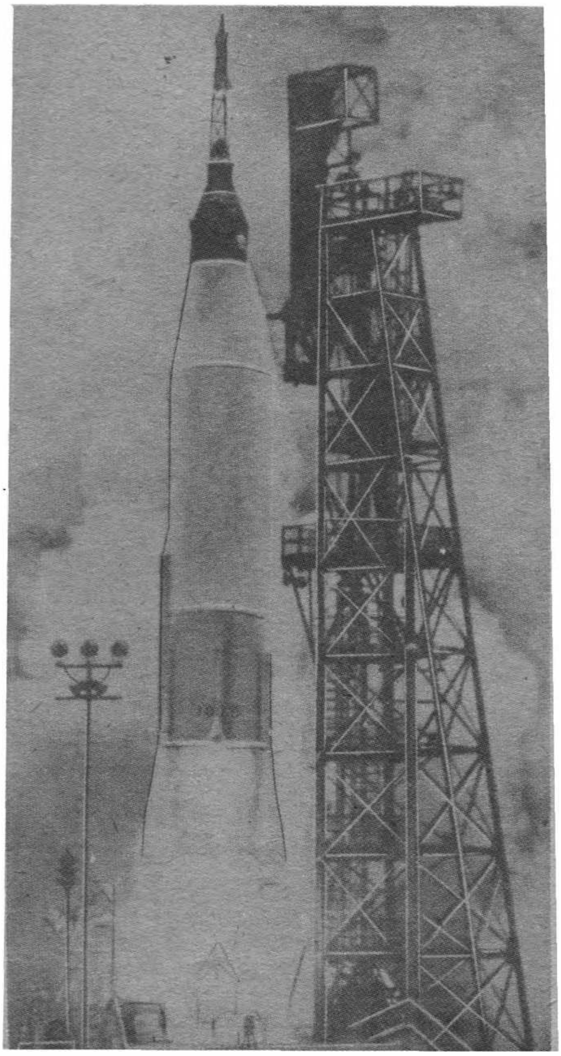
Owing to the technical features of the new proving grounds, it is possible that other countries would wish to use it for civilian scientific or technical purposes. A study is already in progress on the use for the proving grounds by ELDO (European Space Vehicle Launcher Development Organisation). Since 1960 France has supported the idea of European co-operation in the space field and has actively participated in the work of the two existing organisations – ELDO and the European Space Research Organisation (ESRO).

Spaceflight, February 1966

The Lunar Explorers

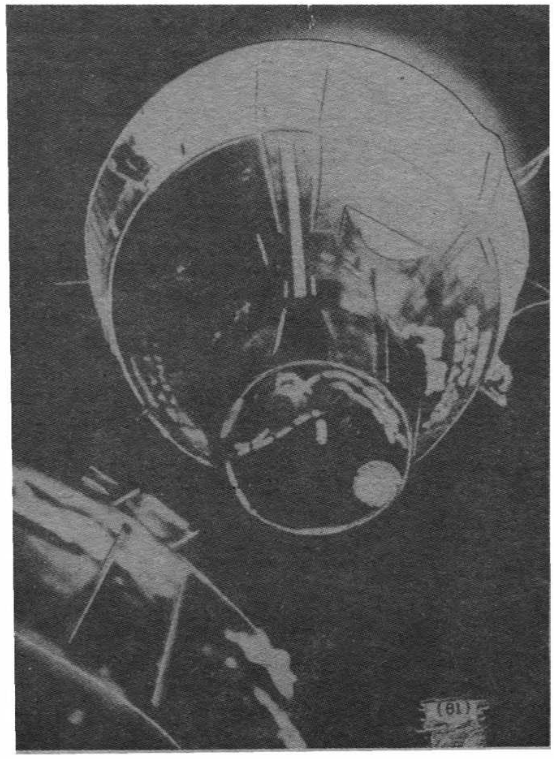
On May 25 1961, before a joint session of Congress, the late President Kennedy announced the go-ahead for project Apollo with these words:

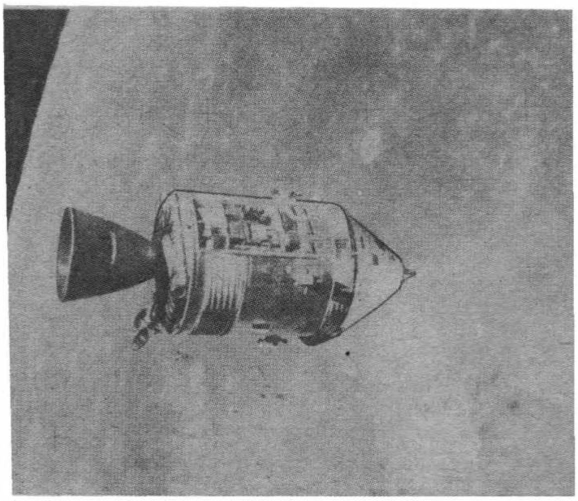
"I believe that this nation should commit itself to achieve the goal, before the decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impres-



The launch on February 20, 1962 of Mecury-Atlas 6 carrying Astronaut John Glenn in the Friendship 7 spacecraft on the first US manned orbital flight.

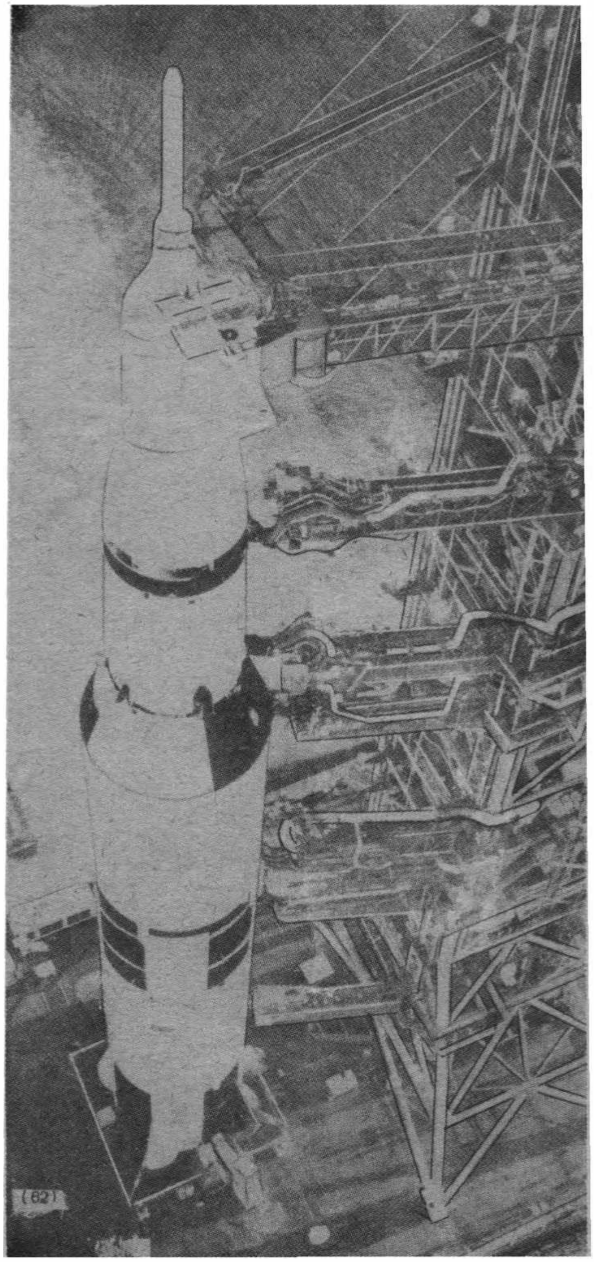
The Gemini 6 and 7 spacecraft in close proximity during the first space rendezvous in December 1965.





In lunar orbit. This view of the Apollo 15 command and service modules was taken from the lunar module shortly before rendezvous and docking.

The Apollo 17 space vehicle at Launch Complex 39A prior to launch of the sixth and final scientific lunar expedition of the Apollo Program.



sive to mankind, or more important for the long-range exploration of space, and none will be so difficult or so expensive to accomplish." Today, with the Apollo programme well up to schedule and NASA still anticipating the first manned landing by 1970, planning groups are now busy formulating the next steps to be taken in manned lunar exploration."

Sixty-five university and government scientists have recommended that the United States use the first manned landing on the Moon as the starting point for a 10-year lunar exploration programme mainly involving manned missions.

Top priority recommended for the early Apollo landing mission is the return of the greatest possible number and variety of lunar material samples (from dust to rock-size pieces).

Second priority for the early Apollo missions would be the emplacing of the Apollo Lunar Surface Experiment Package (ALSEP) by the astronauts. Next in priority would be traversing the lunar surface to describe topographic and geologic features and to supplement this with stereoscopic photographs.

The scientific requirements call for stay times up to 14 days and traverses of one or two suited astronauts aboard roving vehicles up to nine miles from the point of landing.

Spaceflight, May 1966

Europe in Space

As powerful space rockets lift off from Cape Kennedy and the Soviet cosmodrome of Tyura Tam, it is easy to forget that the space age really dawned in Europe. It was at the Peenemünde rocket establishment between 1938 and 1944 that man first mastered the engineering techniques of large rockets.

A quarter of a century after these pioneer achievements on the Baltic coast of Germany, a new surge of activity is slowly gathering momentum in Western Europe vested in the desire to participate in a new age of human affairs of enormous scientific, technological and cultural significance. It is heartening that in these activities the countries concerned regard themselves as a technological family, seeing their future not in isolation but ultimately as partners in a world development. In the furtherance of these ideals, the astronautical societies play a leading rôle and the annual European Symposium on Space Technology, organised jointly by the ALIR, BIS, DGRR and SFA, supported by the industrial association of Eurospace, is now a recognised forum.

Spaceflight, June 1966

Soviet Space Stations

Writing in the newspaper *Krasnaya Zvenda,* Professor Georgi Pokrovsky says "one of the most urgent tasks of cosmonautics is the manoeuvring of spaceships." A rendezvous between spaceships, the assembly of a large habitable station in orbit and the assembly of satellite launch platforms for interplanetary traffic – all these are items on the agenda. Another problem connected with manoeuvring in space "is to ensure a joint flight of several spaceships in a definite formation."

Spaceflight, June 1966

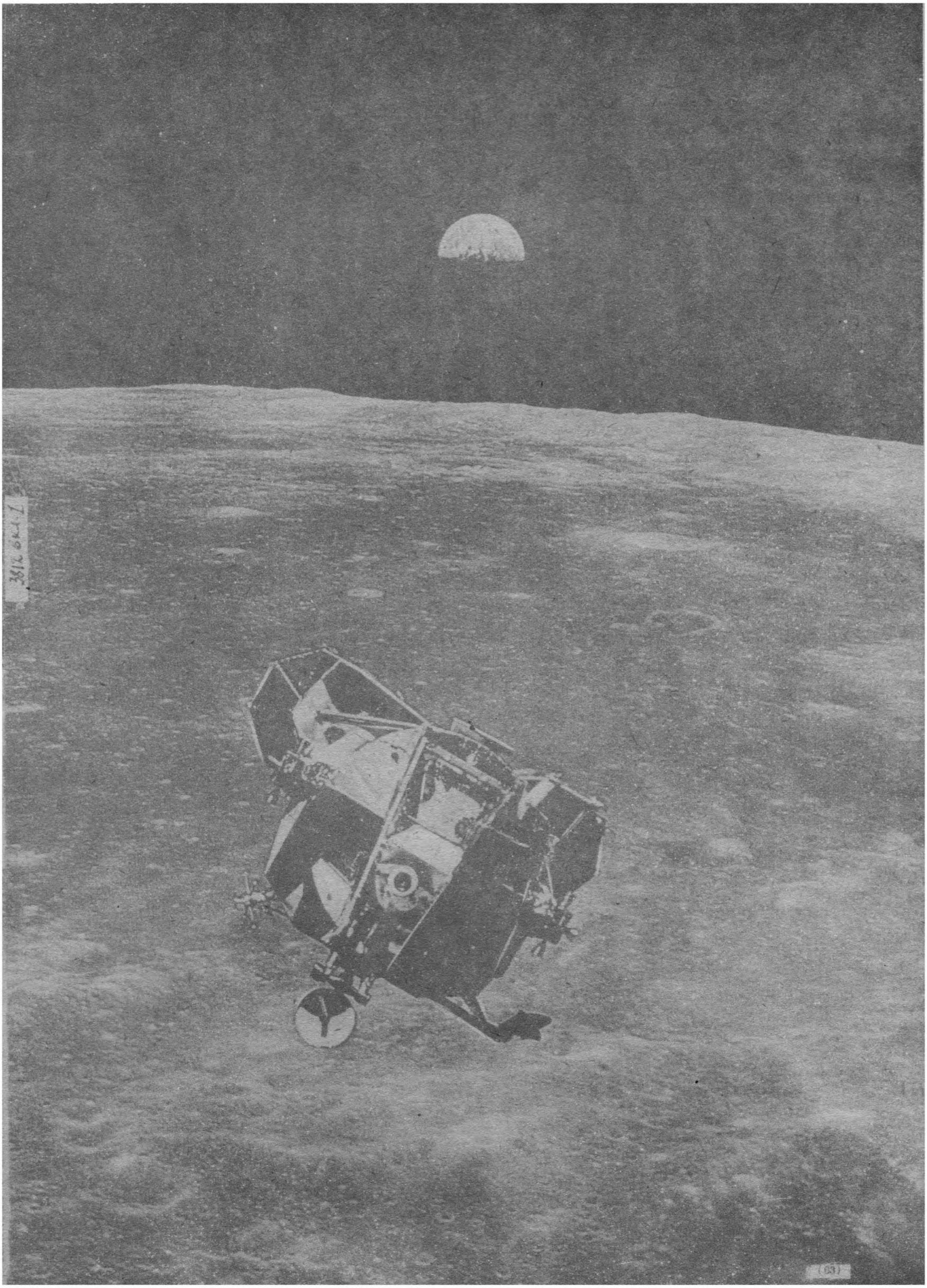
Orbit of Pioneer 6

On March 2, Pioneer 6 passed the Earth at a distance of 7.76 million miles after 76 days of near-perfect operation in heliocentric orbit. The spacecraft was launched against the direction of the Earth's orbital motion around the Sun on December 16 so that it lost speed in solar orbit. The reduced velocity caused the spacecraft to drop behind the Earth and thus fall in toward the Sun.

The craft is following a 311 day elliptical path inside the Earth's orbit of the Sun, but after the initial slow-down caused by the backward launch direction, the spacecraft began to speed up as it moved closer to the Sun on its new orbit.

Designed to study the space between the planets, Pioneer 6 registered a solar wind speed of 1,636,000 mph on February 23, this was close to the highest speed previously recorded on 1,675,000 mph by Explorer 8 in Earth-orbit. Early results from the spacecraft suggest that phenomena in space are even more complex that previously imagined.

Right: The Eagle returning from the Moon's surface as photographed by Michael Collins.



By providing a wide-angle scan around the full circle and an extremely high rate of data return, a "picture" of solar space is being obtained which is ten times more detailed than previous measurements.

Spaceflight, July 1966

First Moon-Satellite

On March 31, at 11.47 am BST, a multi-stage rocket rose from a launch pad of the Tyura-Tam cosmodrome in Kazakhstan to place the Luna 10 spacecraft into a parking orbit close to the Earth. This was the beginning of another major triumph for Soviet space technology – the orbiting of a 540 lb sputnik around the Moon.

Spaceflight, July 1966

Nimbus Triumph

The largest weather satellite yet placed in orbit, Nimbus 2, on July 15, passed its final test objective of two months of continuous operation. Since then it has been used continuously for extensive infrared photographic coverage of hurricane breeding areas in the Atlantic Ocean.

Launched from California on May 15 the 912 lb experimental weather-eye worked perfectly during two months of 24-hr-a-day-operation, in a near-polar, circular orbit 700 miles above Earth.

To bolster the coverage for this year's hurricane season, NASA engineers focussed Nimbus 2's sensitive infrared detectors on the search for hurricane breeding areas.

Spaceflight, November 1966

In Lunar Orbit

At 12.36 pm EDT on August 23 the Lunar Orbiter 1 spacecraft was commanded to make a photograph of the Earth from its position in orbit around the Moon. The frame exposed was one of those periodically required to maintain proper position of the film in the spacecraft camera.

The purpose of the photograph was to obtain data, long of interest to scientists, on the appearance of the Earth's terminator (line dividing the sunlit and shadowed portion of the planet) as viewed from a distance of about 240,000 miles. While from Earth the Moon's terminator is a sharply-defined line, atmospheric effects diffuse the sunlight and yield a view of the Earth's terminator as a gradual shading from light to dark.

The photograph of Earth was read out from Lunar Orbiter by the Deep Space Network tracking station at Goldstone, California, on August 25.

Spaceflight, January 1967

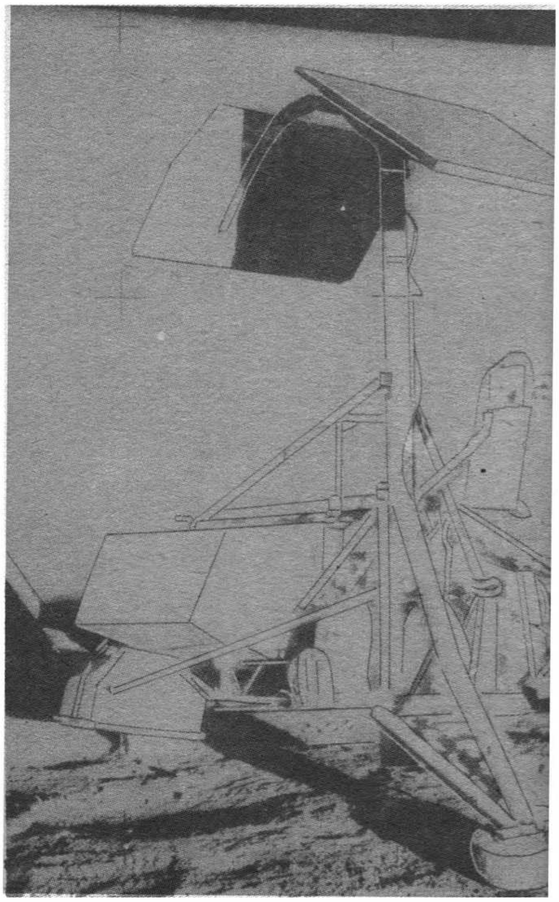
Planetary Billiards

Spacecraft tours of the 1970's may use a system of "planetary billiards" ricocheting via gravitational drag from one planet to the next, according to Dr. Homer Joe Stewart, manager of the Advanced Studies Office of the Jet Propulsion Laboratory, Pasedena.

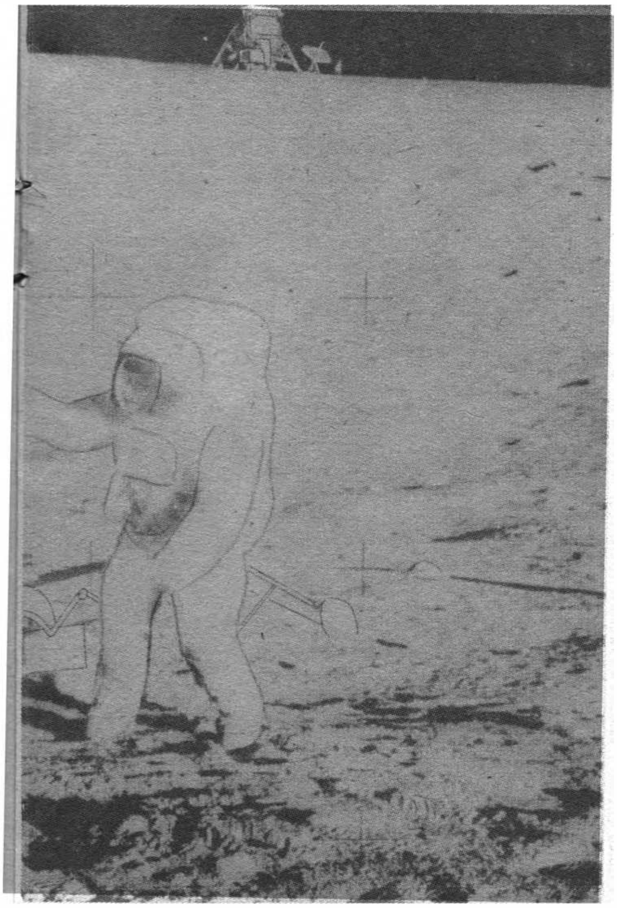
Dr. Stewart notes that Gary Flandro, in a JPL study for the National Aeronautics and Space Administration, postulates that an eight to nine year Grand Tour passing Jupiter, Saturn, Uranus and Neptune is possible starting in 1978. The unmanned spacecraft would be redirected at each planetary approach. The gravitational force would enable the craft to pick up added energy as it changed course. "It would pick up extra energy for nothing," says Dr. Stewart.

The possibilities are fascinating. Larger effects could be achieved in fly-bys of other planets which have greater masses or, in the case of Venus, higher orbital speed. Jupiter, with a mass 317 times that of the Earth, has such a strong gravitational field that large deflections and changes in speed are possible. Computations show that the spacecraft, launched with presently available boosters, would have greatest chance of a successful Grand Tour to Neptune and beyond if launched in October 1978.

Spaceflight, May 1967



This exceptional photograph, taken during the second Apollo 12 extravehicular activity on November 20, 1969, shows two US spacecraft on the surface of the Moon. The Surveyor III spacecraft is in the foreground and the Apollo 12 Lunar Module is about 600 feet away in the background. Astronaut Charles Conrad examines the Surveyor's TV camera prior to detaching it.



An excellent view of the desolate lunarscape showing Scientist-Astronaut Harrison H. Schmitt working at the Lunar Roving Vehicle during the second Apollo 17 extravehicular activity at the Taurus-Littrow landing site. This is the area where Schmitt first spotted the orange soil.

NASA

NASA in 1967

For the United States in space, 1967 was a year of many significant achievements despite the tragedy of the January Apollo fire. Major highlights of the year in the civilian space programme of the National Aeronautics and Space Administration were:

- Successful launch of Apollo spacecraft aboard the first Saturn V.
- Mariner V probed the atmosphere of the planet Venus.
- Lunar Orbiter completed photography of the Moon.
- Major discoveries by three Surveyors landed on the Moon.
- Explorer XXXV provided new information about the Moon's environment.
- ATS-III gave the first continuous weather pictures of Earth in colour.
- New world's speed record in the X-15 aircraft.
- An ultra-violet chart of the surface temperature of the Sun.

Spaceflight, May 1968

First Men Around The Moon

A perfect launch, a 69-mile lunar-orbit, live television pictures of the Earth, Moon and spacecraft interior, Christmas lunch in space and a successful re-entry and recovery: these were the highlights of man's historic first moonflight achieved by Apollo 8. The three astronauts were, of course, USAF Colonel Frank Borman (Commander), USN Captain James Lovell (Command Module Pilot) and USAF Major William Anders (acting Lunar Module Pilot).

Spaceflight, March 1969

ESRO's First Interplanetary Probe

The European Space Research Organisation's first interplanetary physics research satellite, HEOS-A1 (Highly Eccentric Orbit Satellite), was successfully launched from Complex-17B at Cape Kennedy by a Thrust Augmented Improved Delta on December 5, 1968. Its scientific mission is to study interplanetary physics, especially magnetic fields, cosmic radiation and solar wind (outside the magnetosphere) and the Earth's Shock-wave. The achieved initial orbit ranged between 424 and 223 428 km inclined at 28.28 degrees to the equator.

Spaceflight, May 1969

Man On The Moon

One of the most outstanding events in the evolution and continuing history of Man occurred on July 21 1969 when two United States astronauts of the three-man Apollo 11 spacecraft became the first human beings to set foot upon our nearest planetary neighbour, the Moon. In realising one of mankind's greatest dreams and aims, while on the lunar service the two astronauts – Neil Armstrong and Edwin Aldrin – planted a symbolic national flag, took numerous photographs, deployed scientific experiments, collected surface samples and unveiled a plaque which aptly summarised their historic mission by the inscription:

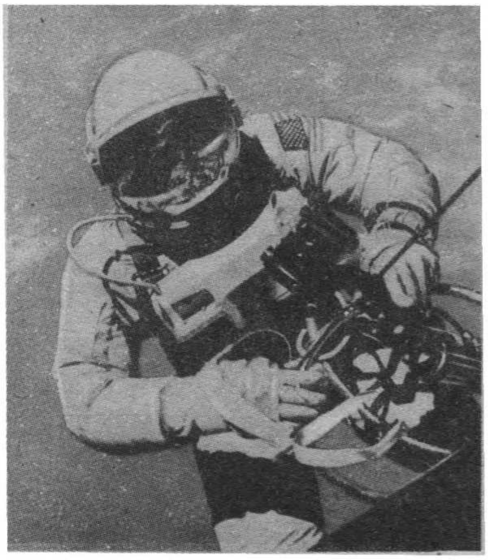
HERE MEN FROM THE PLANET EARTH
FIRST SET FOOT UPON THE MOON
JULY 1969 A.D.
WE CAME IN PEACE FOR ALL MANKIND

Following this activity the two astronauts successfully lifted-off from the lunar surface in the ascent stage of the Lunar Module to rejoin their companion, Michael Collins, orbiting the Moon in the Command and Service Modules before returning safely to Earth on July 24, 1969, eight days after the start of their historic journey of adventure and exploration.

Spaceflight, September 1969

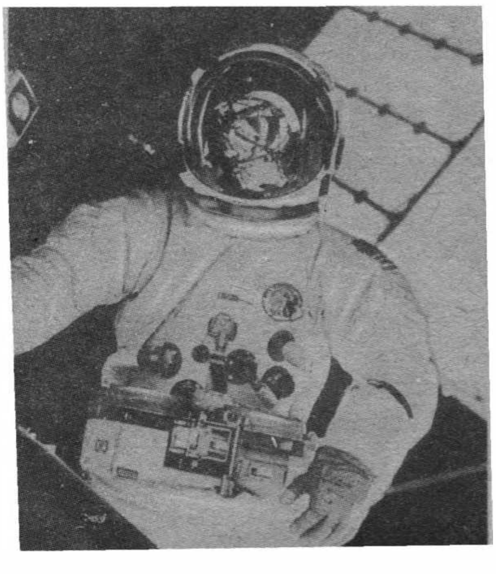
30 YEARS

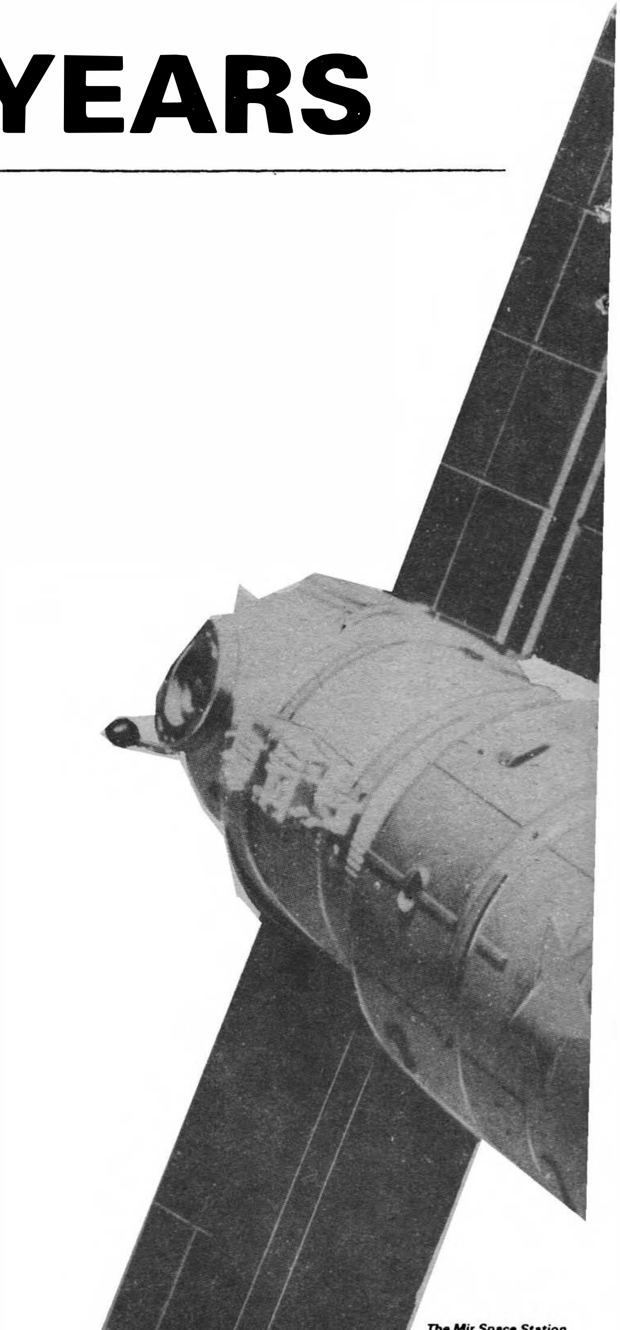
1957



Ed White outside the Gemini capsule on the first US spacewalk

Jack Lousma during a Skylab EVA

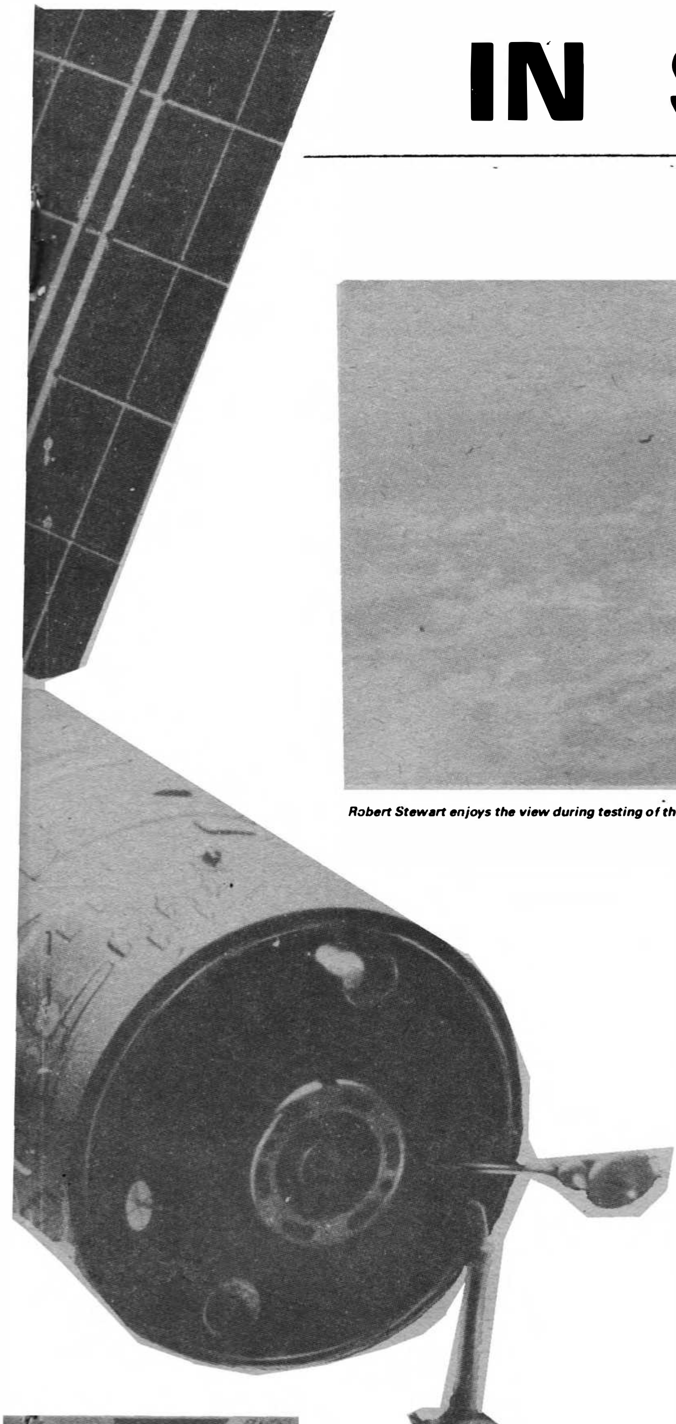


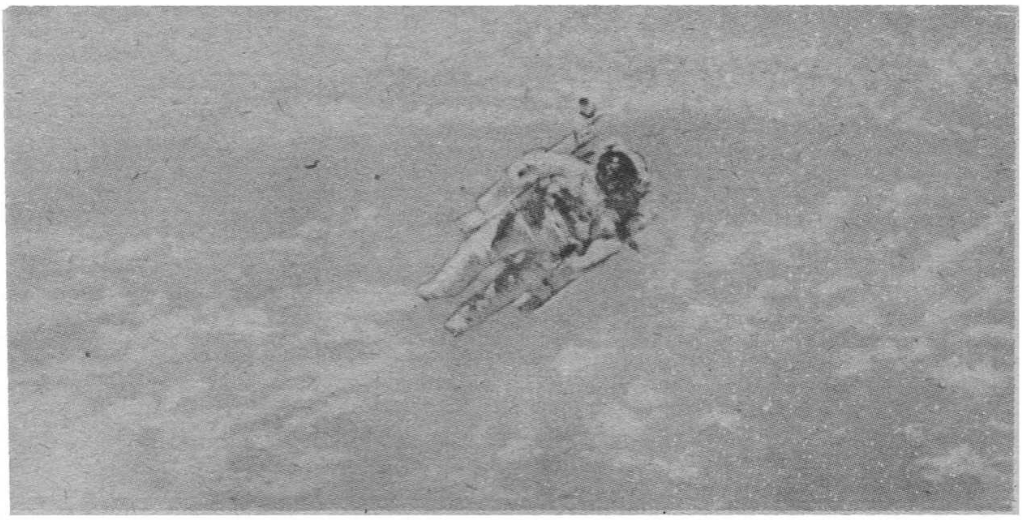


The Mir Space Station

IN SPACE

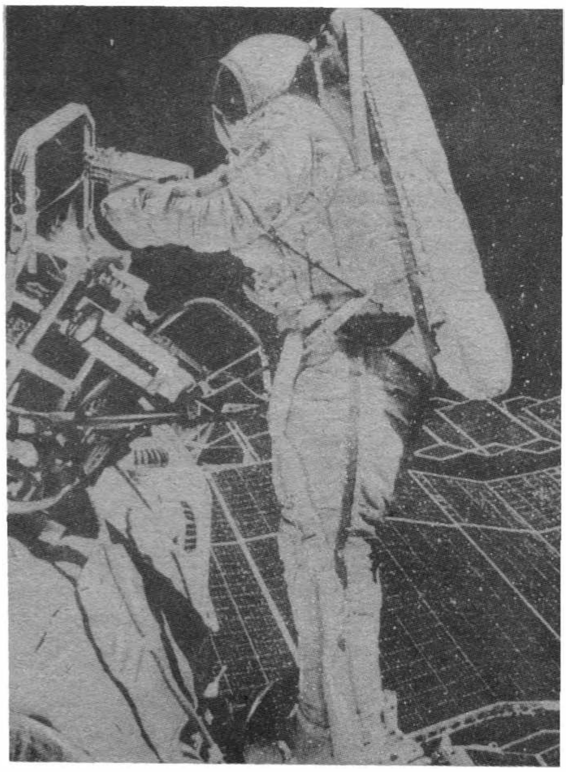
1987

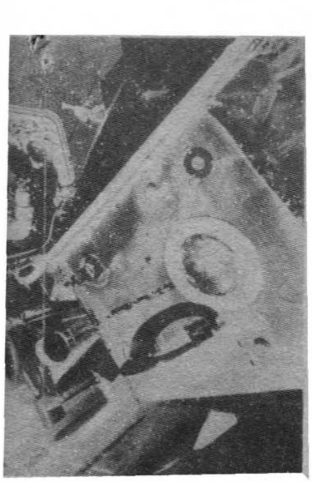




Robert Stewart enjoys the view during testing of the Manned Manoeuvring Unit in February 1984

Svetlana Savitskaya during her EVA from the Slayut 7 space station





Astronaut emerging from the Apollo capsule

Spaceflight

German/US Sun Probe

Agreement on the most advanced international scientific space probe yet undertaken has been reached between the Bundesminister für wissenschaftliche Forschung (BMwF) of the Federal Republic of Germany and the National Aeronautics and Space Administration. The advanced mission, known as Helios, consists of a pair of solar probes which will carry ten scientific experiments closer to the Sun (approximately 28 million miles) than any spacecraft so far scheduled. They will be launched in 1974 and 1975 respectively.

Spaceflight, October 1969

UK Participation in Intelsat IV

During 1965 the first satellite communications system to enter commercial service was inaugurated by Intelsat I, or Early Bird as it was commonly known at the time. Over the past four years the international Intelsat organisation has steadily extended commercial satellite communication capabilities, first with the Intelsat II satellites and more recently with Intelsat III.

A further extension to this service is now planned and will be provided by Intelsat IV. The associated programme is now in an advanced development stage and the spacecraft, which will begin to enter service in 1970-71, will permit a larger number of Earth stations to operate with a greater number of communication channels.

The contract for designing and providing Intelsat IV spacecraft has been placed with Hughes Aircraft Company of El Segundo, California. A considerable proportion of the programme is, however, being undertaken outside the USA.

All spacecraft design is done at Hughes, though the foreign companies involved are assisting in this. British Aircraft Corporation, for instance, has a design team of 30 people at Hughes specialising in particular in design of the structure, power sub-system, position and orientation sub-system, bearing and power transfer assembly and the system test equipment. The prototype and first flight model will be built and tested at Hughes. BAC is responsible to Hughes at that stage for leading an Anglo/French/German group which will comprise a major part of the teams providing test-integration of these spacecraft.

The design and development stage commenced in November 1968 and continues until early 1970 when the prototype completes its test programme. Four flight spacecraft then become available for launch between July 1970 and March 1971.

Spaceflight, November 1969

A Soviet Year in Space

Last year (1969) marked one of the most active and successful years in Soviet space activity with a total of 70 launchings. As during the previous seven years the most numerous satellites were those forming part of the Cosmos programme. However, Soviet space activity advanced on a broad front. The first two launchings of the year were of automatic stations destined to make parachute descents in the atmosphere of Venus during May. A few days later, two manned Soyuz spacecraft in orbit around the Earth linked together to form the world's first 'Orbital Station'. Towards the year's end three more manned Soyuz craft were to be placed into orbit simultaneously.

Two 'Meteor' class weather satellites were launched, and two further Molniya 1 communications satellites were orbited to supplement existing vehicles of this class and expand the 'Orbita' network. Luna 15 was placed into orbit around the Moon and, less than a month later, Zond 7 successfully circumnavigated and photographed the Moon before returning to Earth to make a soft landing in the Soviet Union. Finally, in the field of international co-operation, two Intercosmos satellites made their appearance.

Spaceflight, May 1970

New Generation Tiros

First of the improved TIROS Operational Satellites, TIROS-M, was successfully launched by a Delta-76 from the SLC-2 west launch complex of the Western Test Range, California, on January 23. The launcher was the first of the Delta family to employ six solid-propellent strap-on boosters.

When is Space

by Frank Miles
Head of Independent Television News' space unit.

It all began around Christmas 1968 – after the voyage of Apollo 8 round the Moon. At that time I was a writer in ITN's newsroom and I went to the producer of the 'space unit' to ask if I could join him. It seemed to me that an actual landing on the Moon was going to be the greatest news story not only of my professional life, or even my entire life, but the greatest news story in history. Surely any journalist would want to work on The Big One. He took me on and thus we come to the title of this article.

ITN, watched by between 20 and 24 million people a day, now has five programmes a day:

News at One...	watched by about 3-4 million.
News at 5.45...	watched by the largest audience of any TV news programme in the country, around 11 million.
Channel 4 News...	the most comprehensive of our bulletins, with much more background to the news than others.
Super Channel...	a new half-hour programme with a potential audience of 20 million in 14 countries.
News at Ten...	the original half-hour TV news, watched by about 9 million people every night.

To be worthy of consideration for national television news, space stories need at least one of the following elements:

- A major "first" in space.
- A disaster.
- A good pictorial content.
- A direct concern to our audience (like danger or cost).
- A human interest.
- A strong British interest.

If one can combine a "scoop" with any of these, in journalism one is really in business.

A Major First

It has been customary to lead all our bulletins with the major firsts, such as the first Sputnik, the first man in space, the first spacewalk, the first lunar landing, the first Space Shuttle, and so on. But it is not always "firsts" as such.... we did all the Apollo flights as special programmes and the first three Shuttle flights were specials too.

Disasters

Challenger blew up at around five o'clock in the evening. Within minutes we were on the air with a newsflash and stayed on the air with what we call "an openender" – a programme which has no firm "out" time.

During that live programme and subsequently in each of our bulletins for the next few days, we showed that moment of disaster time and time again. At first it was screened every few minutes because at that time many people were travelling home from work so every few minutes produced a new audience who had not seen it.

A Good Picture

As a programme editor, I must identify the best possible pictures. This is where television excels – its ability to take the viewer right to the scene. We do not need to describe in words, as newspapers and radio do, what driving around on the Moon was like, or a Shuttle launch, or the Challenger disaster – one can see it for oneself.

News?

Frank Miles discussing the future of the US space shuttle with former astronaut Sally Ride, the first US woman to fly in space.

Public Concern

One such concern is the cost of space to Britain. But presentation can be a problem. Referring back to the need for a picture to illustrate a story, it is difficult to illustrate the desire of, say, the BNSC to get more money to spend on space. How do you illustrate someone asking for money and someone else refusing it?

One space story that invariably gets the phones ringing is the one that tells people something is about to fall out of the sky, maybe on their heads! The danger has been there several times.

Human Interest

Sending a man into space is infinitely more exciting to viewers than sending a dog, mice or brine shrimp.

What, then, if the man were to be British? Well, now.... the fact a Britain was to fly in space was confirmed to me by a Rear Admiral's refusal to deny it! I rushed to the telephone and rang ITN. It was put into *News at 5.45* and dealt with more fully on *News at Ten*. Incidentally, a few days later the Prime Minister (who had been abroad when we ran the story) was asked in the Commons about our report and she said "it's not true". But two weeks later, the MoD admitted it *was* true.

Strong British Element

A recent example, enhanced by the element of a scoop, began early in 1983 when I was told that Britain might have its own independent launch vehicle. The story went dead on me... until late that year when first I was told it would be a single-stage-to-orbit vehicle, then that it would have a top-secret propulsion unit, then that it would take off and land horizontally. It sounded exciting but I was warned, it was so top-secret I could not run anything on it.

However, one day in the summer of 1984, I was astonished to find that – as a project – it was to be made public at the Farnborough Air Dispaly. Its name was Hotol (Horizontal Take Off and Landing). Back at ITN I saw the editor at once and we broke the story on *News at Ten* the next night. Within minutes the ITN switchboard was jammed.

The Press Association carried a story that night saying the MoD and Rolls Royce denied knowing anything about such a project. Next day British Aerospace rang and read me a statement they were to issue which actually confirmed everything we had said.

Britain is likely to lose the lead we could have had with Hotol. Part of the reason is this business of keeping from the media things that need not, in fact, be secret. While many other nations with a space programme are hyping their sometimes inferior wares, in the UK we are engaged in hiding our very substantial lights under the biggest bushels ever.

The subject of this article was the title of a lecture by Mr. Miles to the British Interplanetary Society on March 17, 1987.

Primary mission of the new weather satellite was to observe day and night cloud cover in the visible and infrared spectra for live transmission to world-wide users, to observe global cloud cover daily in the visible and infrared spectra and to record these data for later playback and processing. Secondary objectives were to gather heat balance data and to identify proton flux levels at the spacecraft altitude. The 682 lb spacecraft is boxshaped with three solar panels attached at one end; with panels deployed the width is 14 ft.

Spaceflight, May 1970

Japan: Fourth into Orbit

After four unsuccessful attempts, Japanese space engineers succeeded in launching an artificial satellite into orbit in February, thus becoming the fourth member of the exclusive 'space club' whose members are nations who have orbited satellites.

The satellite, the fourth stage of a Lambda 4S5 rocket, is taking two hours and 24 minutes to complete one circuit of the globe.

Spaceflight, July 1970

'We have a problem!'

An explosion in the Service Module (SM) of the Apollo 13 spacecraft en-route to the Moon was to characterise the most agonising, exacting and tense manned space flight yet undertaken. It happened at 04.08 BST on April 14, 1970 when the astronauts were some 200,000 miles from Earth. Commander James Lovell announced: 'We have a problem!'.

Just how great the problem was soon became apparent. The loss of vital services to the Command Module (CM) threatened the very existence of the crew who were forced to use the docked Lunar Module as a 'lifeboat' for four tense and dangerous days.

Between Houston Mission Control and the astronauts, the most incredible rescue operation was put into effect. Drawing upon the LM's life-support, power and propulsion systems, the crippled Apollo 13 was able to divert its course around the Moon, sustain the crew, and achieve a safe return to Earth.

Throughout the ordeal, Mission Control relayed to the astronauts computer data, instructions and words of encouragement. Without the dedicated efforts and technical expertise of ground personnel, supported by a superb computing and simulation complex, there can be little doubt that James Lovell, Fred Haise and John Swigert would have perished.

Spaceflight, September 1970

Record Flight of Soyuz 9

All duration records for manned space flight were broken by the Soyuz 9 spacecraft which completed 286 orbits of the Earth between June 1 and 19, during a mission lasting 424 hr 59 min. The record was previously held by Gemini 7 astronauts Frank Borman and James Lovell who completed 206 revolutions in 330 hr 35 min in December 1965. The longest previous Soviet spaceflight was that of Vostok 5 cosmonaut Valery Bykovsky in June 1963; his 81-orbit mission lasted 119 hr 6 min.

Spaceflight, September 1970

LUNOKHOD 1

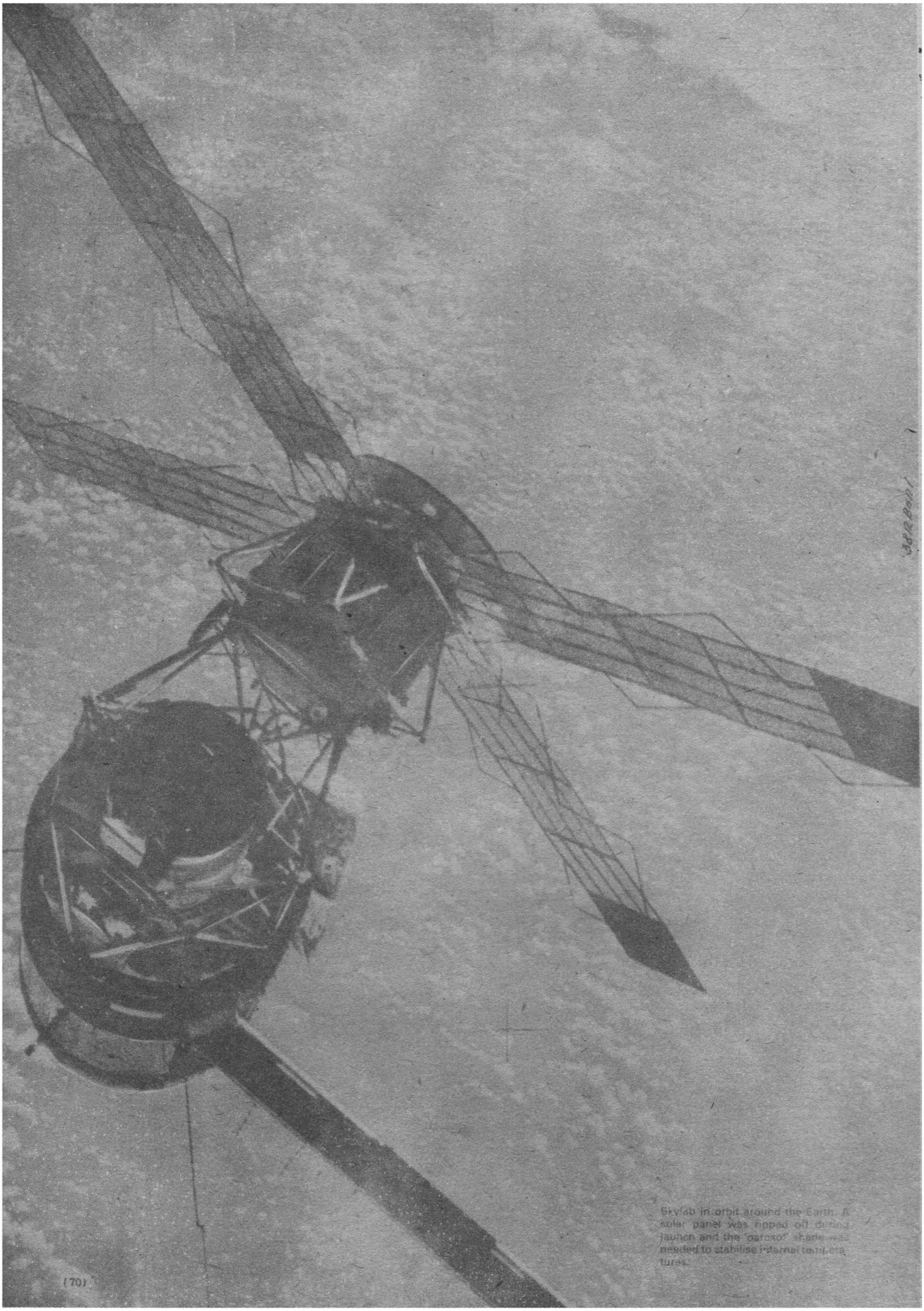
After moving down the ramp of the Luna 17 descent stage on November 17, Lunokhod 1 had travelled 198 metres by November 21.

During its first days on the Moon the eight-wheeled mobile laboratory performed a number of experiments under Earth supervision which ranged from the analysis of moonrock to studies of X-rays from remote parts of the Universe.

Spaceflight, March 1971

East-West Space Co-operation

An encouraging step towards world cooperation in astronautics has been an agreement between the USSR Academy of Sciences and NASA which includes the exchange of moon rocks and discussion of future



Skylab in orbit around the Earth. A solar panel was ripped off during launch and the 'parasol' shade was needed to stabilise internal tempera-tures.

planning for the exploration of the Moon and the planets. Also listed for joint consideration are 'the improvement of existing weather data exchange, research with meteorological rockets, techniques for studying the natural environment, and the expanded exchange of data in space biology and medicine'.

Whether this degree of collaboration will lead to joint activity in Earth-orbit aboard orbiting space laboratories and joint planetary expeditions only time will tell. Last year small teams of US and Soviet engineers met in Moscow to consider the possibility of standardising rendezvous and docking procedures for future manned spacecraft to facilitate space rescue.

The text of the present agreement, which follows discussions held in Moscow between January 18/21, 1971, was initialed by Academician M. V. Keldysh, President of the USSR Academy of Sciences, and George M. Low, Acting Administrator of the National Aeronautics and Space Administration.

Spaceflight, August 1971

Mars From Orbit

Within a week of Mariner 9 starting to photograph and probe the surface of Mars from orbit, scientists reported the following findings:

1. Mars has a large equatorial bulge – a surprise discovery.
2. The planet is 'gravitationally rough', exerting a strong gravitational field globally and locally. Local 'gravitational anomalies' may be caused by 'mascons', concentrations of dense material similar to lunar mascons lying beneath the Moon's maria or dry seas.
3. Water vapour, with its implications for life, is present in some abundance in the atmosphere over the South Polar Cap. This is the first measurement of water in the Martian atmosphere by a spacecraft, although in 1969 Earth-based studies detected water in the Martian atmosphere.
4. Mars is hot, but slightly cooler than recorded by previous US Mariner probes in 1965 and 1969. The Martian daytime high is about 240 deg. Kelvin with the temperature peaking at mid-afternoon, not at noon. The nighttime high is about 200 deg. Kelvin.
5. The temperature of the Martian atmosphere is a constant 350 deg. Kelvin from near surface out to 40 km.
6. The great dust storm shrouding Mars was clearing, affording Mariner's twin TV cameras an opportunity to photograph craters and mountains and other interesting surface features. Neither the constituents of the storm nor its cause had been identified.

The findings were announced on November 19, by chief scientific investigators for the Mariner 9 project during a Press Conference at California's Jet Propulsion Labouratory (JPL), control centre for the Mars mission.

Spaceflight, February 1972

The Space Shuttle

A statement by President Nixon, January 5, 1972:

"I have decided today that the United States should proceed at once with the development of an entirely new type of space transportation system designed to help transform the space frontier of the 1970's into familiar territory, easily accessible for human endeavour in the 1980's and 90's.

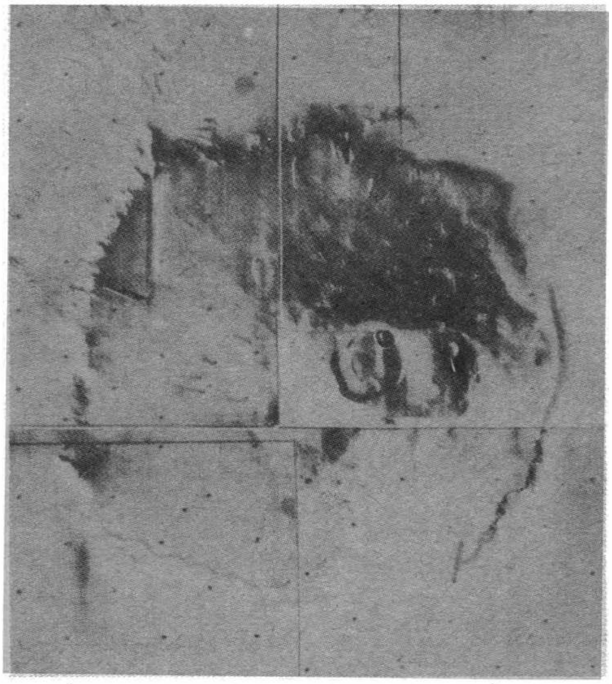
This system will centre on a space vehicle that can shuttle repeatedly from Earth to orbit and back. It will revolutionize transportation into near space, by routinizing it. It will take the astronomical costs out of astronautics. In short, it will go a long way toward delivering the rich benefits of practical space utilisation and the valuable spinoffs from space efforts into the daily lives of Americans and all people....

The new system will differ radically from all existing booster systems, in that most of this new system will be recovered and used again and again – up to 100 times. The resulting economies may bring operating costs down as low as one-tenth of those of present launch vehicles....."

Spaceflight, April 1972

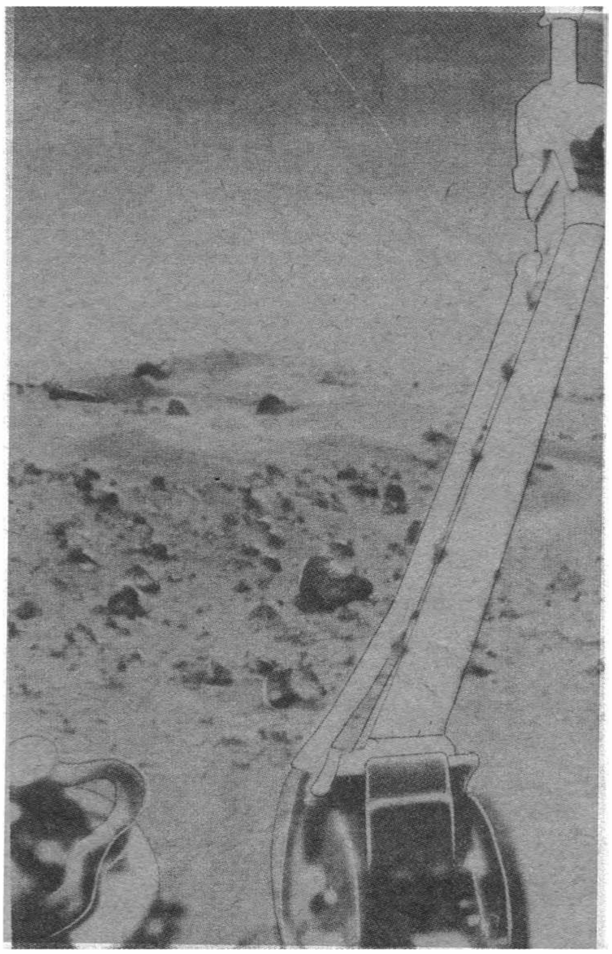
Triumph of Skylab

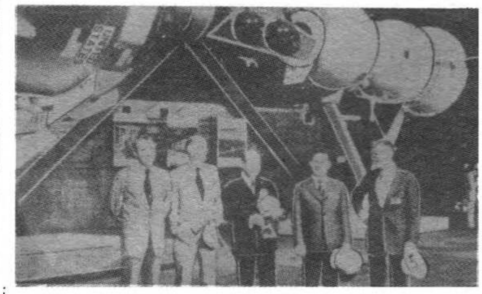
After the huge success of Charles Conrad and his crew in salvaging



Nix Olympica, the gigantic volcanic mountain on Mars photographed by Mariner 9 in January 1972. The mountain is more than twice as broad as its most massive counterpart on Earth. The main crater at its summit is 65 km (40 miles) in diameter.

A boom on the Viking 1 spacecraft extends meteorological sensors four feet above the Martian surface. A notable feature of the landscape is the field of dunes which are remarkably similar to many seen in the deserts of the Earth.





The five ASTP crewmen during an inspection of a mockup of the Apollo and Soyuz spacecraft in a docked configuration at the Kennedy Space Centre. *L. to R.* – Vance Brand, Tom Stafford, Alekei Leonov, Valeri Kubosov and Donald Slayton.

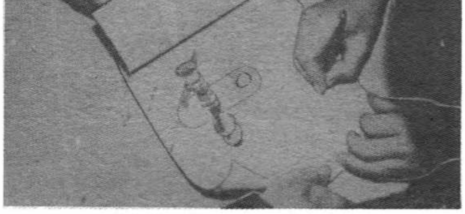
Apollo–Soyuz Test Project

It was May 1972 that the then President of the United States, Richard M. Nixon, signed an agreement with A.N. Kosygin, Chairman of the Soviet Council of Ministers, for mutual cooperation in manned space flight. The three years that elapsed between that date and 1975 provided both sides with a unique opportunity for working together on a compatible rendezvous and docking operation that would be demonstrated in flight during a short duration mission involving two space vehicles developed for a very different purpose. Apollo had been designed to carry three men to the vicinity of the Moon; Soyuz was a ferry vehicle for space station operations and formed the mainstay of future Soviet activity in Earth orbit.

The incompatibilty of Apollo and Soyuz docking and environmental control systems necessitated the development of a structual interface which would simultaneously serve as a docking adapter and airlock. The chosen design was 10 ft 4 in long and 4 ft 8 in. in diameter, ample space for two astronauts to remain inside during pressure adjustments and crew transfer from one vehicle to the other. The Soyuz spacecraft normally flies with an oxygen-nitrogen atmosphere at about 15 lb/in^2 but consultation with Soviet engineers brought an agreed reduction to 10 lb/in^2 for the duration of the docked activity. Apollo, pressurised with almost pure oxygen at 5 lb/in^2, remained the same and the 4,500 lb. Docking Module had responsibilty for supplying the necessary gas mixture and pressure regulation for crew transfer.

At 16:55 the two spacecraft swept into ATS coverage. At 17:05 Soyuz went to inertial hold and rolled 60 degrees to present the correct alignment with the Docking Module. Slowly Stafford pulsed the reaction control thrusters from the left command module couch and moved Apollo into dock with Soyuz at 17:09. Just 13½ minutes later the docking system was fully retractred and the two vehicles were locked firmly together. Approach speed at soft capture was just 1 ft/sec and from the Russian spacecraft came the comment, "Soyuz and Apollo are shaking hands now!"

An historic moment of ASTP was the signing during the rendezvous of the official joint certificate. Cosmonaut Valeri Kubosov is seen here adding his signature.



the crippled Skylab space Station, NASA is now preparing to launch the second astronaut team on Friday July 27, 12 days earlier than originally planned.

After docking with Skylab on May 26, the astronaut team first succeeded in erecting a 22 x 24 ft. 'parasol' made of layers of nylon, Mylar and thin aluminium foil, from a scientific airlock in the side of the orbital workshop, which effectively lowered internal temperatures. On June 7, a daring EVA repair operation by spacewalkers Conrad and Kerwin then succeeded in freeing the jammed solar 'wing', restoring a large part of the station's electrical power.

***Spaceflight*, August 1973**

Europe's Spacelab

An unprecedented new international cooperative project is provided for in a Memorandum of Understanding signed in Washington on September 24 last by Dr. James C. Fletcher, NASA Administrator, and Dr. Alexander Hocker, Director General of the European Space Research Organisation (ESRO). Nine countries, under the aegis of the European Space Agency, will design, develop, manufacture and deliver a 'Spacelab' flight unit which will be an important element of NASA's Space Shuttle system. Spacelab will have two elements, a pressurized manned laboratory module permitting scientists and engineers to work in normal shirt-sleeve environment and an instrument platform, or pallet, to support telescopes, antennae and other equipment requiring direct space exposure.

***Spaceflight*, April 1974**

Encounter With Mercury

Between March 23 and April 3 Mariner 10 took over 2,000 television pictures of the planet Mercury. In addition it carried out searching investigations of the planet's magnetic field and of the interaction of this field with the interplanetary plasma, it measured Mercury's ultra-violet and infra-red radiation, and has given us a new estimate of the planet's mass of unprecedented accuracy.

***Spaceflight*, August 1974**

Aryabhata in Orbit

India's first Earth satellite, named Aryabhata after the great fifth century astronomer and mathematician, was placed into orbit on April 19, by a Soviet two-stage Intercosmos rocket from the cosmodrome at Kapustin Yar near Volgograd. The orbit achieved – very close to design values - ranged between 564 and 623 km inclined at 50.4 deg. to the equator; period 96.41 min.

***Spaceflight*, Aug/Sept 1975**

Ariane – ESA Heavy Launcher

The original concept of this multistage rocket (known as the LS3) was proposed by the French space agency CNES (Centre National d'Etudes Spatiales) and subsequently offered as a European project during the European Space Conference of December 20, 1972. At this meeting the French Minister for Industrial and Scientific Development reiterated that his country was still very interested in a European heavy launcher – a statement made against the background of the declaration that ELDO'S Europa 2 rocket, which had suffered a number of failures, was not viable and should not be used again. The LS3 would be a little less costly to develop than Europa 3 (the concept then favoured to follow Europa 2), and France was willing to undertake the bulk of development, supplying about 60% of the funding in return for receiving the main contracts.

***Spaceflight*, February 1976**

Second German Sun Probe

Helios B, the second solar probe built in West Germany under a cooperative agreement with NASA, was successfully launched from Cape Canaveral on January 15, Launched by a Titan IIIE/Centaur TE 364-

4, the probe follows its twin, Helios 1, which ascended from the Cape on December 10, 1974.

The German/US research programme - already paying large dividends in the quality of information concerning interactions between the Sun and the Earth - is the largest European international space venture to date.

Spaceflight, March 1976

The Rising Sun

Seven Japanese satellites are now orbiting the Earth, all of them launched by Japan with its own means from facilities near Kagoshima or on Tanegashima Island. The first six were developed and placed into orbit under the auspices of the Ministry of Education by the Institute of Space and Aeronautical Science (ISAS), University of Tokyo. The last one - ETS 1 (Engineering Test Satellite 1), launched on September 9, 1975 – marks the debut, in space operations and applications, of the National Space Development Agency (NASDA), now Japan's most important space organisation.

Spaceflight, March 1976

On The Golden Plains of Mars

The landing of Viking 1 was incredible in its textbook precision. Its smoothness from the separation of the Lander from the Orbiter to the Lander touchdown astounded all of us who have been conditioned to expect hairy problems and miscalculations on interplanetary missions. The 599 kg (1,320 lb.) automated laboratory came down at 8 ft/sec at 12 hr. 12 min. 7 sec. GMT July 20, in Chryse Planitia, the Golden Plains, at 22.4 degrees north latitude and 47.5 degrees west longitude. It was 4:13 pm Mars local time.

Spaceflight, October 1976

Soyuz 22

On September 15, 1976, at 09.48 (all times expressed in GMT), the Soviet Union launched Soyuz 22, carrying a two-man crew – Commander Valery Bykovsky and Flt. Eng. Vladimir Aksyonov. Bykovsky had first flown as pilot of Vostok 5 in June 1963, while Aksyonov, selected in 1973, had not flown in space before.

The main aim of the mission, undertaken under the programme of co-operation among Socialist countries in the exploration and peaceful uses of outer space, was to "check and improve scientific and technical methods and means of studying from outer space geological and geographical features of the Earth's surface, in the interests of the national economies of the Soviet Union and East Germany."

To accomplish these tasks Soviet engineers had modified the back-up ASTP Soyuz. Primarily, this involved removing the ASTP androgynous docking equipment and replacing it with a special photography canister.

This canister housed the MKF-6 multispectral photography complex, designed by Soviet and East German specialists, and manufactured at the Carl Zeiss factory in Jena, East Germany. Apart from the ASTP Soyuz, which carried some American equipment, this was the first time that foreign equipment had been carried onboard a Soviet manned spacecraft. However, foreign equipment had been used many times in Soviet unmanned satellites launched under the Intercosmos programme.

Spaceflight, February 1977

On Humanity's Role in Space

The role of humanity in space seems to fall naturally into two categories:

1. The utilisation of humans in space, with their unique capabilities and attributes in order to serve the direct and indirect needs of humankind.
2. The existence of humans in space for humanistic interests, including sociological, societal, political and ethical reasons.

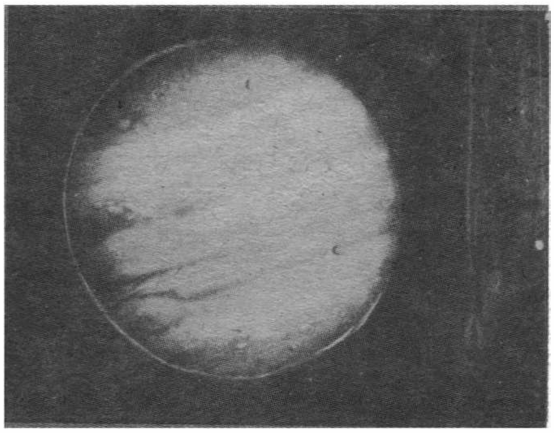
In this view, the Humanisation of Space is seen as a dichotomy: seeking ways to open up space for humanity, and bringing space down to Earth for use by humanity.

Spaceflight, February 1978

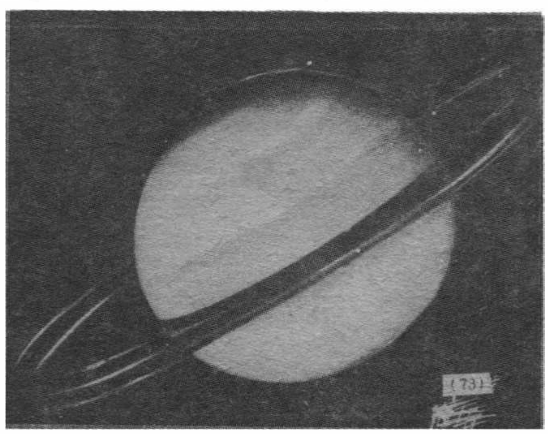
Ultraviolet view of Venus, Mariner 10, February 1974.

Utopia Planitia, Mars, Viking 2, September 1976.

Jupiter with satellites Io and Europa, Voyager 1, February 1979.



Computer enhanced view of Saturn, Voyager 1 and 2, 1981.



The New Landsat

On March 5, 1978 the National Aeronautics and Space Administration launched a new, improved satellite from the Western Test Range in California to monitor the Earth's natural resources. The 900 kg (1,980 lb.) Landsat 3 entered a 917 km (570 mile) circular, near polar orbit. Circling the globe every 102 minutes, its remote sensors view a 185 km (115 mile) wide strip of the Earth running nearly north-to-south at an angle to the equator of 99 deg.

In this type of orbit, surface coverage of the Earth proceeds westward, with a slight overlap, such that the globe is covered once every 18 days. The spacecraft's orbit is synchronous with the Sun. Thus Landsat 3 (like Landsat 2) crosses the equator at the same time (9:30 a.m. local time) every orbit. This results in consistent and constant lighting of Earth, the best condition for the spacecraft's imaging systems. Synoptic, repetitive coverage of Earth's surface under consistent observation conditions is required for maximum utilisation of the multispectral imagery.

Spaceflight, August 1978

Tiros-N Weather Satellites

The first in a series of eight new operational meteorological satellites - the TIROS-N series - was launched from the Western Test Range near Lompoc, California, on October 13. The new satellites are designed to replace the current NOAA series spacecraft and incorporate major technological advances.

Spaceflight, January 1979

Black Holes and Globular Clusters

Data from an American-British-European satellite, the International Ultraviolet Explorer (IUE), suggest the possibility of a massive black hole at the centre of some groups of stars in the Galaxy called globular clusters.

Six of these clusters, three of them X-ray sources, have been the subject of close examination by a group of scientists headed by Dr. Herbert Gursky and Dr. Andrea Dupree, both of the Harvard-Smithsonian Centre for Astrophysics, Cambridge, Mass.

IUE was launched by NASA into a modified synchronous orbit near the equator in January 1978, in cooperation with the European Space Agency (ESA) and the British Science Research Council (SRC), to study a wide range of celestial objects in the ultraviolet (UV), one of the most important regions of the electromagnetic spectrum.

Spaceflight, January 1979

First Navigational Satellite System

Navigation by satellite has escaped much of the publicity associated with other space applications such as communications and Earth resources observation, yet today many hundreds of ships regularly obtain navigation fixes of higher accuracy than can be obtained by any other method from observation of Earth-orbiting satellites. The satellites that provide this service form part of the Transit system.

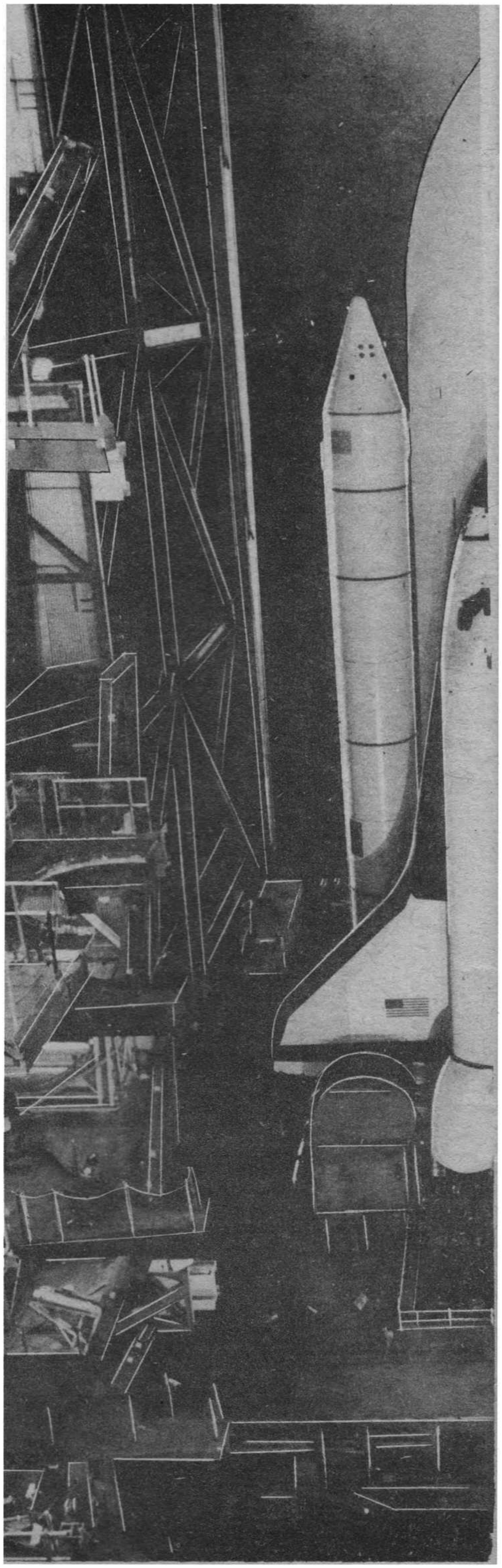
Transit is a mature operational programme. There are currently six satellites in use and another was ready for launch in 1978 if required. The first of the improved Nova type scheduled for launch in 1979. However, the new NavStar navigation satellites of the joint services Global Positioning System are now being flight-tested and will eventually provide a continuous high-accuracy navigation service not only for shipping but also for aircraft, ground troops, other spacecraft and general civilian applications.

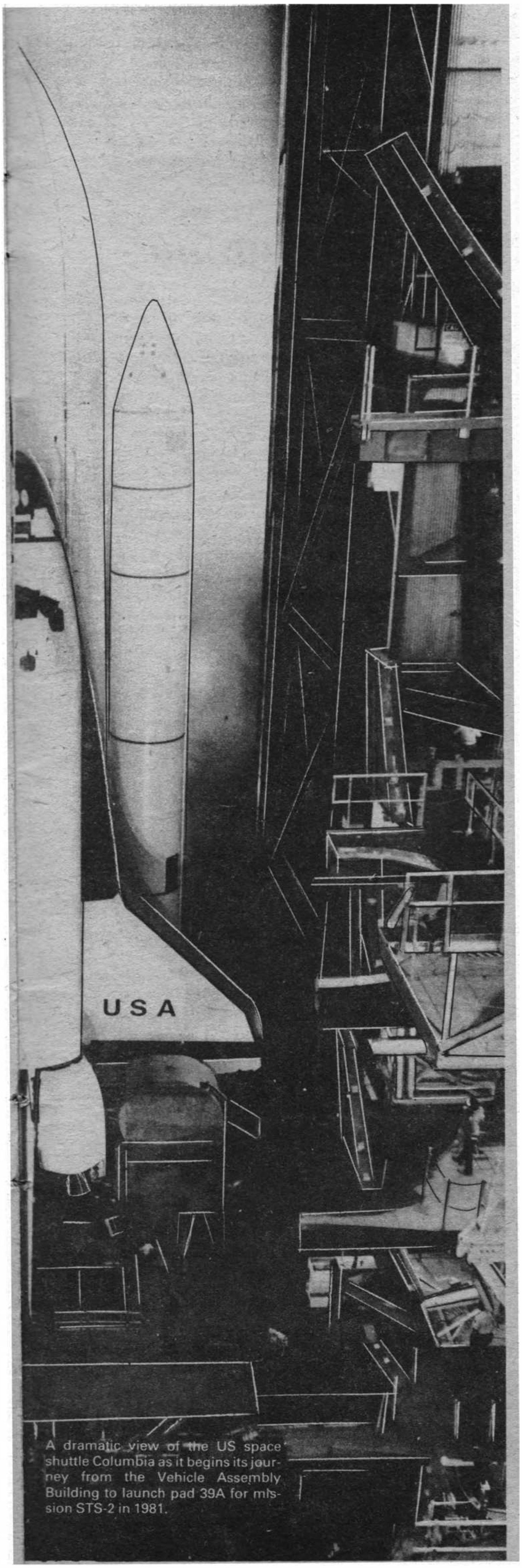
Spaceflight, February 1979

Remote Manipulator System

Canada is contributing "a mission critical" element to the Space Shuttle. It is the Remote Manipulator System (RMS) which is an analogue of the human arm. The RMS will be able to perform such duties as transferring astronauts from a disabled Orbiter to a rescue vehicle, repair, recalibration and even retrieval of malfunctioning satellites.

Spaceflight, December 1979





A dramatic view of the US space shuttle Columbia as it begins its journey from the Vehicle Assembly Building to launch pad 39A for mission STS-2 in 1981.

USSR Space Station Plans

A recent interview by the deputy Director of the Soviet Space Research Institute has thrown new light on Russian space plans for the 1980s.

Professor Georgi Narimanov outlined the three main objectives of the Soviet piloted programme:

- Developing reusable transport and ferry systems
- Finding the correct balance of cosmonauts and automation in operating orbital stations
- Setting up space stations with crews of 20 to 30 cosmonauts orbiting for two to three years.

Experience gained with Progress and Soyuz spacecraft would help with the design of reusable Shuttle craft which would have two stages, both recoverable. However, the most unusual aspect of the interview was when the Professor stated that "to obtain maximum lift capacity for the first stage it will probably use an air-breathing engine."

Large stations, which will follow the advanced Salyut, will be made up of modules which can be docked with a central service area. Such modules will be standardised and of either cylindrical or spherical form.

A number of inferences can be drawn from this interview. First it gives us a good idea as to the size of space station the USSR is working towards. Such a station would require a Shuttle carrying a load of eight to ten crew members to make operations economically viable.

Second, it confirms the approach of linking different modules and units together to build up such a station, highlighting the need for a space tug, of which Cosmos 929 was almost certainly the precursor.

Third, whilst it confirms that the USSR is very much involved in Shuttle development, the interview confuses the issue further as to the true nature of the Soviet Shuttle. Two years ago there was some speculation that the Russians might use air-breathing hypersonic flyback aircraft. If this is the case it shows them moving on a very different track from the Americans, one which Western research in the 1960s appeared to regard as unpromising.

The timing of the introduction of the Soviet Shuttle is still unclear. This interview, because of its lack of precision, indicates this will be later rather than sooner.

Spaceflight, May 1980

UV Satellite Reports

The International Ultraviolet Explorer satellite, launched in 1978, has provided scientists from 17 countries with more than 9,000 images of astronomical objects that could not be obtained by ground-based instruments. Nearly 200 scientists have used these images in support of about 250 research programmes and more than 100 scientific papers have been written about the results of these observations. The satellite is helping to answer the most basic questions in astronomy – what stars, nebulae and galaxies are and how they develop.

Spaceflight, May 1980

The Voyager Project

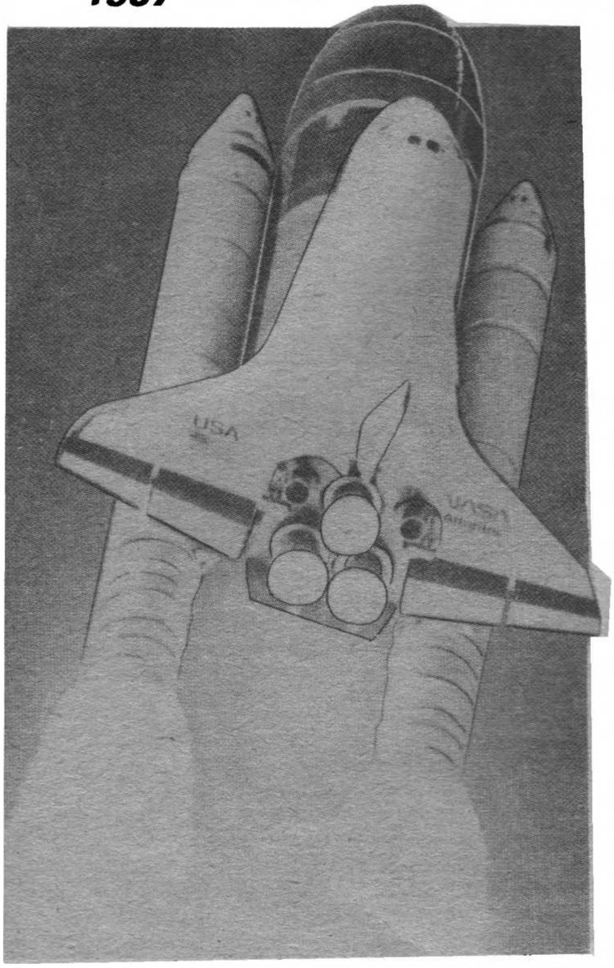
On November 12, one of the world's most spectacular space missions reached its climax when Voyager 1 flew behind the rings of Saturn to record with cameras and other instruments how sunlight is affected as it shines between the ring particles. The spacecraft which left Cape Canaveral on September 5, 1977 had previously returned superb colour pictures of Jupiter and a number of its moons and a wealth of scientific data. The close encounter with Saturn included an examination of the moon Titan - bigger than the planet Mercury - Mimas, Dione and Rhea.

Spaceflight, February 1981

Encouraging Results in Materials Processing

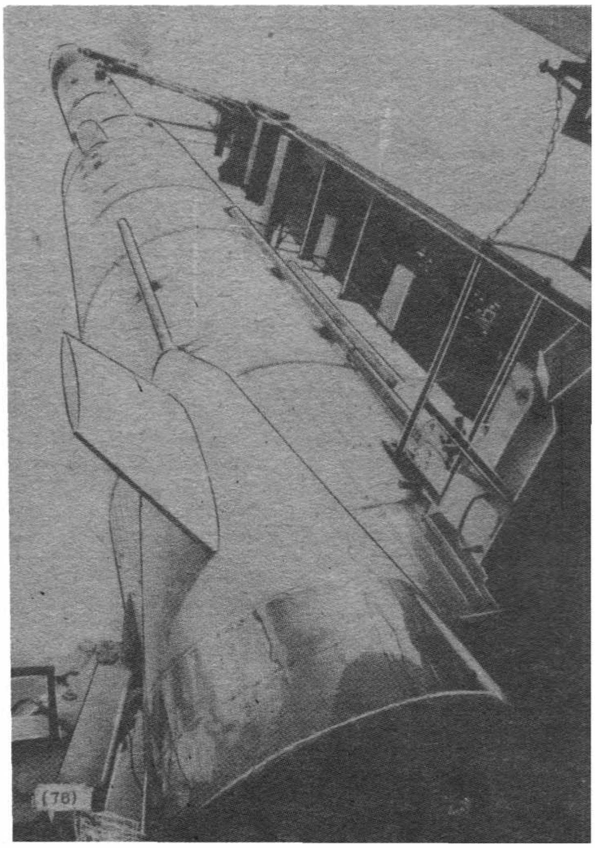
The experiments carried out by the Salyut crews so far have confirmed that production at micro-gravity can substantially improve the quality of various materials, both organic and inorganic.

The use of holography in metallographic studies has for some time



Atlantis clears the launch tower to begin its first mission in space, October 3, 1985.

Ariane "propellant mock-up" for testing of launch procedures, February 1979.



been pioneered in the Soviet Union by the Moscow Institute of Steel and Alloys, but for the needs of materials-processing research in space an entirely new, portable holographic installation had to be designed by the Moscow Physics-Technical Institute.

We may also expect substantial improvements in the electric heating installations used in such work. The Splav and Kristall furnaces were designed to attain maximum temperatures of 1,000-1,200°C.

All this should substantially increase the range of materials prepared in mirco-gravity conditions and make it possible to proceed gradually to pilot-plant production of the most promising of them in orbit.

Spaceflight, May 1981

The Voyage of Columbia

It has been a long wait; almost six years since an American manned spacecraft has been counted down. Years of great emptiness, of paper plans, hearings, problems foreseen and unforeseen, months and years of delay as NASA sought to turn concepts into hardware; a multitude of tiles that were not everything they must be, main engines that were subject to violent explosions. At times, it seemed as if launch day (April 12, 1981), like the end of the rainbow, would always be just beyond reach. But suddenly, launch day is at hand. Columbia is ready to set out on a voyage of exploration to the unknowns of the multi-shock waves of such an unusual configuration, through the vacuum of space and finally the first Mach 25 re-entry and landing of a winged vehicle.

In a London press conference on June 19, Columbia commander John Young said that lift-off was very "soft", like a fast elevator. Before the flight he thought that it would be like being "hit on the back of the head with a hammer". Noise levels in the cabin were also less than on Apollo-Saturn V launches.

Spaceflight, Aug/Sept/Oct 1981

Ariane into Space

The events of June 19 at Kourou in South America spread a glow of well-being down the corridors of ESA headquaters in Paris. Ariane LO3 took off at 12.32.59 GMT carrying three satellites (Meteosat 2, Apple and CAT-3) into a highly eccentric orbit of 201.3 x 36,206.7 km. Since the planned orbit was 200 x 35,800 km it represents an accuracy to within about 1 per cent.

Spaceflight, October 1981

Voyager 2 at Saturn

In the early hours of August 26, Voyager 2 swept past the planet Saturn in a close encounter. Pictures of the rings and satellites of higher resolution than those from Voyager 1 were obtained, until the craft emerged from behind the planet and revealed that its camera platform was jammed. This problem was solved and Voyager went on to complete its mission.

The magnificent successes of Voyager, like those of Viking, shows what can be achieved in the exploration of the Solar System. If all goes well, Voyager 2 will reach Uranus in January 1986 and Neptune in August 1989.

Spaceflight, November 1981

Satellites to the Rescue

The Soviet Union's COSPAS satellite was launched on June 30, 1982 as part of the international COSPAS/SARSAT demonstration project in which the United States, Soviet Union, Canada and France are using space technology for finding civil aircraft and ships in distress.

The project located four accident sites and saved seven lives in its first month of operation.

Spaceflight, February 1983

IRAS in Orbit

The Infrared Astronomical Satellite (IRAS) was placed accurately into its 900 km orbit by a Delta 3910 from the Vandenberg Air Force Base in California on January 26. Although the launch went without incident, it

was in doubt until the last hour or so due to very strong winds at 12,000 m. It was not until the final meteorological report was received that all was "go" for launch.

Spaceflight, June 1983

Flight of Spacelab

Originally scheduled for September 30, various technical and equipment problems pushed the launch of STS-9 back to November 28.

The main objective was to test the entire Spacelab system. This involved evaluation not only of the hardware and experiment, but also data transmission to Earth, ground support procedures and flight crew work.

Spaceflight, April 1984

ESA Satellite Moved

With the growing number of satellites in the geostationary orbit, 36,000 km above the equator, the increasing risk of collision between working and deactivated satellite has to be faced. This orbit is vital for communications and weather satellites. The only practical control is to remove satellites once they have reached the end of their useful lifetimes. ESA recently carried out such a move with GEOS 2. Launched in 1978, with a planned life of two years, GEOS, designed to measure electric and magnetic fields as well as particle streams in the magnetosphere, proved such a valuable tool for scientists that its mission was extended until the end of 1983. Its work came to an end as the fuel supply for orbit and attitude control ran out.

On January 24 and 25, the European Space Operations Centre in Darmstadt, west Germany boosted GEOS into a higher orbit where it will present no risks either for satellites in the geostationary orbit or for those in transfer orbit. This is the first time that ESA has decommissioned and removed one of its satellites from the geostationary orbit.

Spaceflight, June 1984

Repair of Solar Max

On February 14, 1980, a 2300 kg astronomical satellite was launched by NASA from Cape Canaveral into a 570 by 563 km orbit. After several days of tests, it was ready to begin gathering data on the Sun, then in a period of maximum activity. This task gave the satellite its rather unimaginative name: the Solar Maximum Mission or, simply, "Solar Max".

Unfortunately, on November 23, 1980, three fuses in the attitude control system blew, leaving Solar Max with no fine-pointing capability for four of its six telescopes.

Fortunately, Solar Max was the first of a new generation of satellites specifically designed for in-flght servicing. Thus, in early 1981, before the Shuttle had ever flown, plans were formulated for a rescue in the spring of 1984, when the satellite's orbit would have decayed to within the Shuttle's range.

Spaceflight, October 1984

Aerobee Retires

Aerobee, the sounding rocket that paved the way for manned space flights and deep probes into space, retired on January 17, with its 1037th launch. The flight, from White Sands Missile Range in New Mexico, officially concluded a long and prodigious record that spanned more than 37 years.

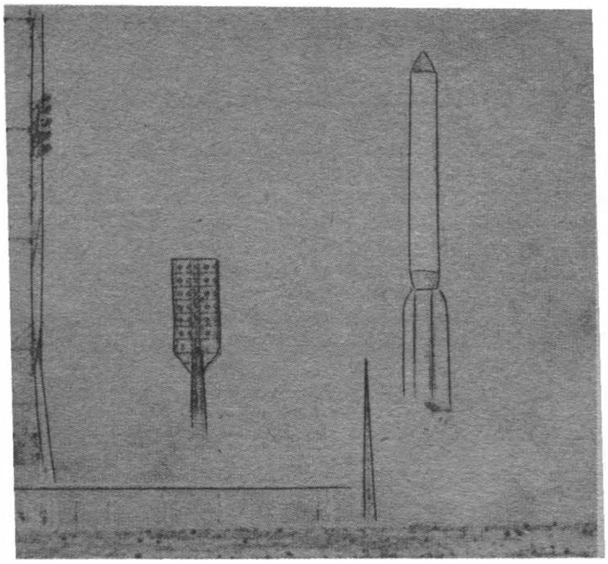
Spaceflight, July/August 1985

Soviet Space Agency

A civilian Soviet space agency has been formed by the USSR to act as a counterpart to the American NASA and other national space agencies.

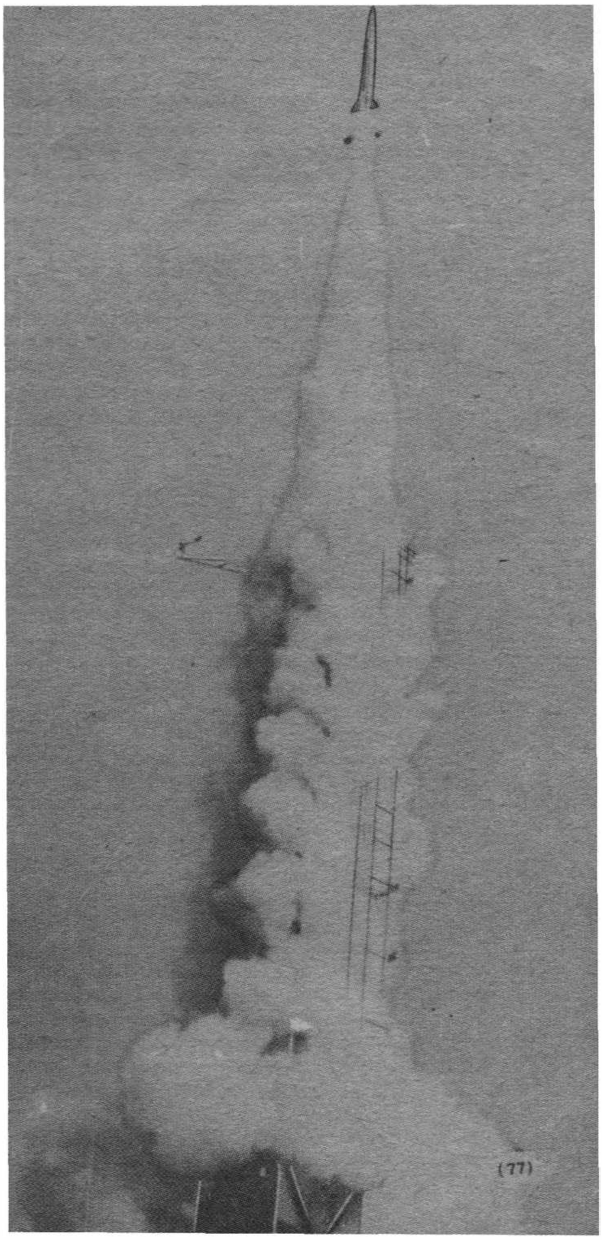
Called Glasvkosmos–an acronym for the Main Administration for the Creation and Use of Space Technology for the Economy and Scientific Research–its primary function will be to manage Soviet space science, space applications and co-operative international space ventures.

Spaceflight, January 1986



The Proton rocket has been the workhorse for Soviet space activities since the mid 1960's.

Aerobee research rocket launch from Wallops Island.



Venus Unveiled by Vega Probes

On June 9, Vega 1, which was launched on December 15, 1984 drew close to the planet after travelling some 500 million kilometres. Explosive charges were then fired automatically, causing the Venus descent capsule to separate from the other part of the spacecraft, which will visit Halley's comet.

In the early morning of June 11, the descent module hurtled into the Venusian atmosphere at about 11 km per second. It was then about 125 km above the planet's surface.

This capsule then divided into a landing module and a balloon-carried sensor module, as planned. The former made a successful soft landing on Venus' surface, whilst the balloon section began to drift at an altitude averaging about 50 km.

Spaceflight, February 1986

Voyager Returns Uranus Picture

The first clear picture of Uranus was returned by the Voyager 2 spacecraft at the end of November while it was still eight weeks away from the planned close encounter with the giant planet on January 24.

Scientists at the Jet Propulsion Laboratory, Pasadena, California, which has managed the epic Voyager mission to the outer Solar System, used computers to combine six images returned by the spacecraft's narrow angle camera on November 28.

They were taken from a distance of 72.3 million kilometres and clearly show the outer, or epsilon, ring which lies some 51,200 km from the planet's centre. This is the most prominent of Uranus' nine known rings.

The closest approaches to Uranus and its satellites all occur within five and a half hours, which compares unfavourably with the spacecraft's previous encounters with Jupiter (35 hours) and Saturn (13 days). One reason for this is the unusual axial tilt which places the planet and its moons in one plane relative to Voyager.

Spaceflight, February 1986

72 Seconds to Disaster

Challenger rose off the launch pad at 1638 GMT on January 28 and was climbing smoothly when it suddenly exploded in a hugh fireball about 90 seconds after lift-off. Debris from the 100 ton spacecraft came down over the Atlantic Ocean about 29 kilometres down range from the Cape Canaveral launch site.

Spaceflight, March 1986

Space Station Build-up Begins

On March 12, the Soviet space programme broke with tradition and gave its first advanced notice of a space launching scheduled for the following day. The mission was the first of a series of launchings to the new Soviet space station, Mir, which was placed in orbit on February 20.

The start of manned operations at the space station is to be led by veteran cosmonaut Leonid Kizim and space endurance record holder Vladimir Solovyov.

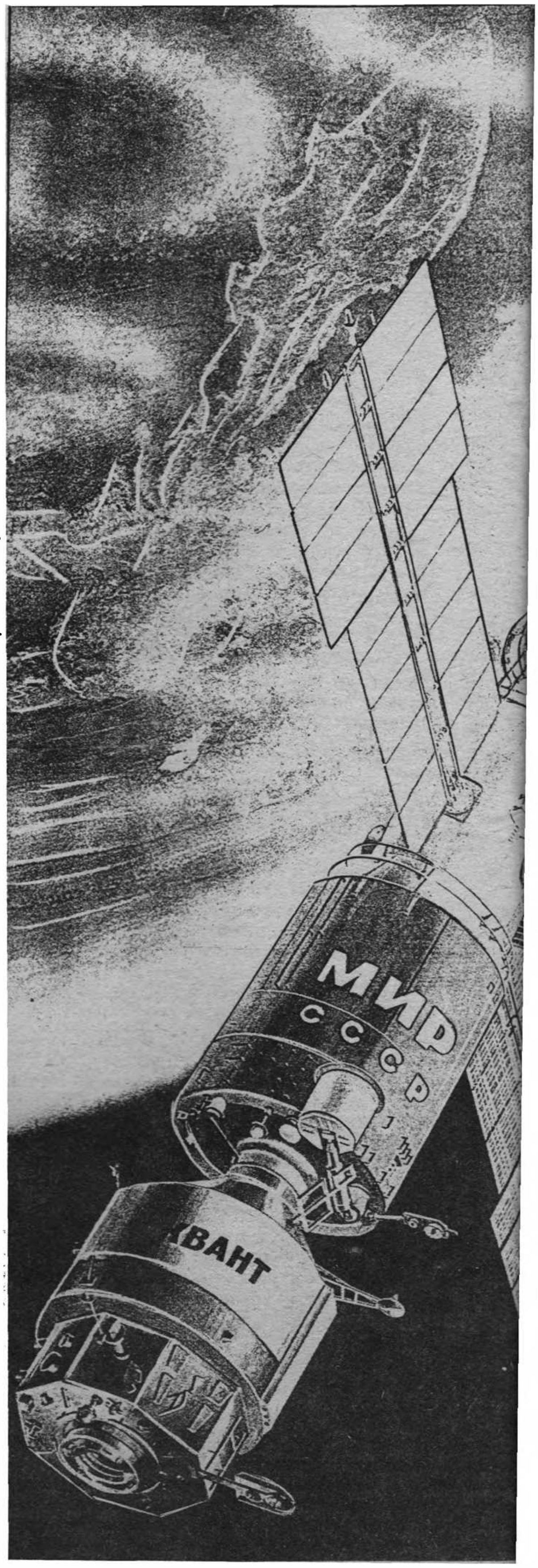
The new space station has six docking ports for manned or unmanned capsules ferrying to and from the Earth. Its launch, by a Proton booster, is seen as the first stage in Soviet plans to form a new modular space station complex.

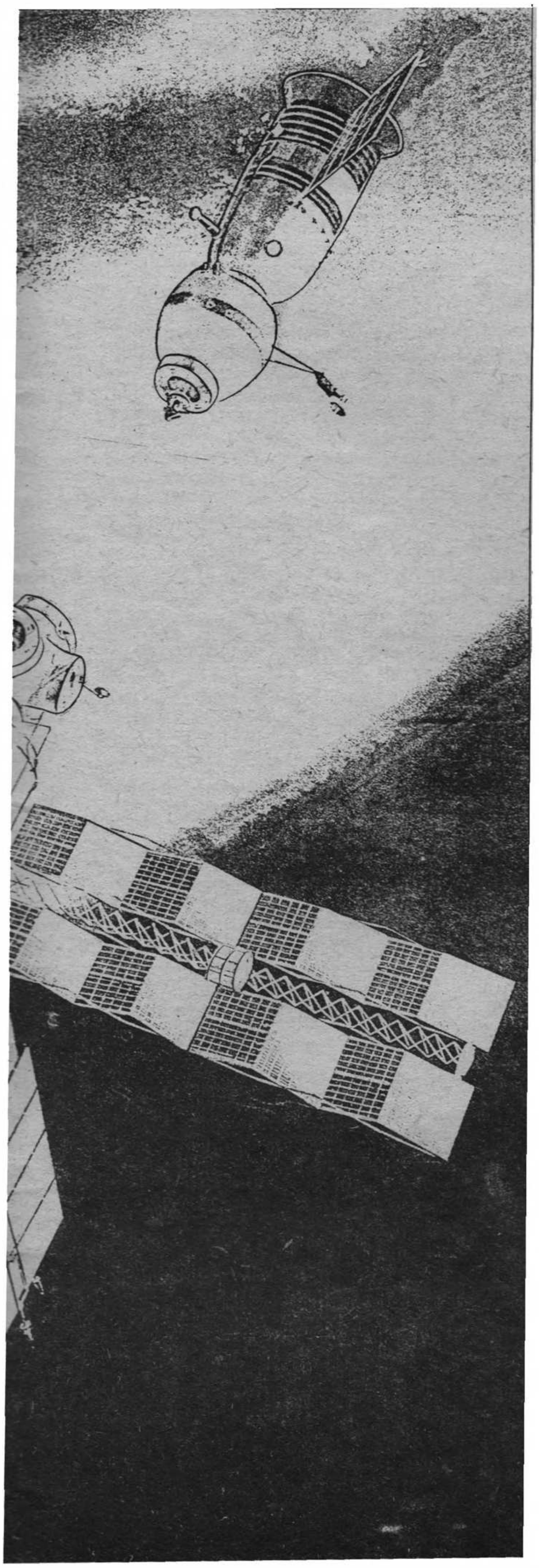
Spaceflight, April 1986

ESA's Giotto Encounters Halley

Shortly after 1 am on March 14, 1986 on the third floor of the European Space Operations Centre (ESOC), Darmstadt, Germany, spontaneous applause rippled from one room to the next. These were the rooms in which the scientists with experiments aboard the ESA satellite Giotto had their data receiving instruments. Here they had sat for most of the day anxiously waiting to see if years of work would bring success or failure.

Spaceflight, May 1986





Japanese Launch Heralds New Era

The launch of Japan's newly developed H-1 booster on August 13 put the West back on the space map following successive Space Shuttle, Titan, Ariane and Delta failures in the first half of 1986. For Japan, a country which has already proved its tenacious ability to capture massive consumer markets in the electronics and car industries, it also marks the dawn of a new era.

Early in 1986 NASDA initiated development of the H-II rocket which will serve as a successor to the N-I, N-II and H-I launch vehicles.

The H-II rocket is designed to serve as NASDA's main workhorse in the 1990s to meet the demand for larger satellite launches at a lower launching cost and still maintain a high degree of reliability.

Spaceflight, November 1986

Spacemen at Mir

On February 7, 1987 the Soyuz TM-2 spacecraft docked at Mir space station and cosmonauts Yuri Romanenko and Alexander Laveikin took up residence for an expected record-breaking stay in space. The docking manoeuvre followed a night-time launch two days earlier from Baikonur.

Spaceflight, March 1987

First Launch of Carrier Rocket

The Soviet Union launched the first version of its Heavy Lift Launcher called Energia (Energy) at 1730 GMT on May 15. It had been revealed on May 13 during a three day visit to the Baikonur Cosmodrome by Soviet leader Gorbachev that preparations were underway for the launch of "a new general-purpose carrier rocket capable of putting both re-usable orbital craft and large spacecraft for scientific and economic purposes into low orbit, including modules for long-term stations".

Spaceflight, July 1987

Mir Mission: Third Solar Array Installed

Two EVAs, on June 12 and 16, have enabled cosmonauts Romanenko and Laveikin to instal a third solar array on Mir thereby increasing its power to well above the 10 kW provided by the station's original two arrays. The new array was carried up to Mir onboard the Kvant module launched on March 31.

Spaceflight, August 1987

Soviet Earth Survey Platform

The largest civilian Earth survey spacecraft ever launched was put into orbit by the Soviets on July 25.

Weighing between 15 and 20 tons, the Earth resources/ocean survey platform was launched by the Proton booster.

The spacecraft, designated Cosmos 1870, carries multi-disciplinary science instruments that will provide information for hydrology, cartography, geology, agriculture and the environment.

The platform, similar to but larger than the US Earth Observing System planned for launch in 1996, will supply the newly formed Soyuzkarta organisation with data for sale world-wide. As such it will compete with the US Landsat and French Spot satellites in an area of space development that is likely to expand dramatically by the end of the century.

Soyuzkarta has been set up by the Soviet Department of Geodesy and Cartography to sell photographs of the Earth taken from space.

A training centre has been set up in Dushanbe, Tajikistan, to teach foreign specialists how to interpret space photographs.

Spaceflight, September 1987

Orbital operations in progess at the Mir space station complex. Extra power is now available at the station following the addition of a third solar array. Further scientific modules, like the Kvant module, are expected to dock at the station and significantly enlarge its range of activities before the end of 1988.

Listening to the Cosmonauts

by J. Branegan

Manned Soviet spacecraft transit UK air space five times a day on at least 150 days each year. When near the UK these craft make regular use of simple VHF radio communications – the signals are strong and can easily be copied.

It might appear at first sight that nothing useful could be gained from listening to these signals unless the listener is fluent in Russian. This is far from being the case, the Space Station is like a house – when empty it is silent, but when occupied it is alive with sounds of all kinds, many of which have nothing to do with the actual voice communications themselves. Are the cosmonauts leaving?, or are they going outside on EVA? Are they enjoying themselves, or are they overworked? All this and a great deal more is revealed by the way in which downlink communications are used and by the background noises which are inadvertently superimposed on them. Anyone with a simple amateur radio 144 to 28 MHz converter attached to a Citizens Band FM radio can listen to and learn from these microphones in space.

Where Can The Cosmonauts Be Heard

Figure One shows a great circle map centred on the English Midlands. The inner circle enclosing the UK and most of Western Europe is the Mir space station footprint. If a Mir orbit enters this inner circle it is above the UK horizon and any transmissions from the complex will be heard in the UK.

However, Mir does not talk to UK stations. So the outer circle is also important, because it defines the geographical limits inside which any distant ground station or ship can talk to Mir, and hence, cause Mir to be heard in the UK. It will be noted that this allows UK stations to hear Mir as it talks to stations to its east in Russia, or to Russian Communications ships as far away as Nova Scotia, Canada, or the Straits of Gibraltar.

As Figure One shows there are usually five orbits crossing UK air space each day. On the diagram these orbit tracks are numbered in sequence on the approach part of each track, before it gets above the UK horizon. The five daily in-range orbits form a continuous sequence. Separation between in range portions is about 94 to 96 minutes, so the five orbit block takes about six and a half hours to complete. Then, for the succeeding 17.5 hours, no Mir orbits pass in range of the UK.

When in range of Russian Ground Control stations or ships, the Mir downlink signal is transmitted on a frequency of 143.625 MHz frequency modulation. The signal is strong and requires no special reception facilities. Figures three and four show frequencies used by other Russian spacecraft.

When Can The Cosmonauts Be Heard?

Careful listening to the VHF downlink can produce a useful picture of the cosmonauts' day. As there are at present only two of them, they are working a standard "Moscow Time" day, in order to keep in step with their Ground Controllers. "Office Hours", are therefore usually 0500 UT to 2000 UT, with weekends featuring a relaxed procedure, whereby they can "miss" several orbits and not be heard at all, or, more often, they can use the downlink to talk to their families.

There is one important additional feature which governs when they are likely to be heard. This is the steady precession of the plane of the Space Station orbit, which moves a little under six degrees west (24 minutes of time) each day. The practical effect of this precession is shown in Figure two, an adaptation of a standard Kettering Group plot, showing all orbits heard in the UK between April 14 and June 17, 1987. The gradual shift of the orbit plane moves the "five orbits in range of the UK" earlier each successive day, with the result that in just over two months the "in-range orbits" window has cycled through 24 hours. In April the first orbit of the window is just heard, late in the cosmonauts' day. By May the orbits heard are occurring in the morning and early afternoon, and by mid June the orbits heard have crossed the cosmonauts "Sleep Time" gap, and are being heard in the late evening. The important point about Figure Two is the 2100 UT to 0500 UT sleep period. The dearth of orbits heard on either side of this gap meaning that on some days only one orbit is heard in UK.

This pattern can be expected to recur regularly:

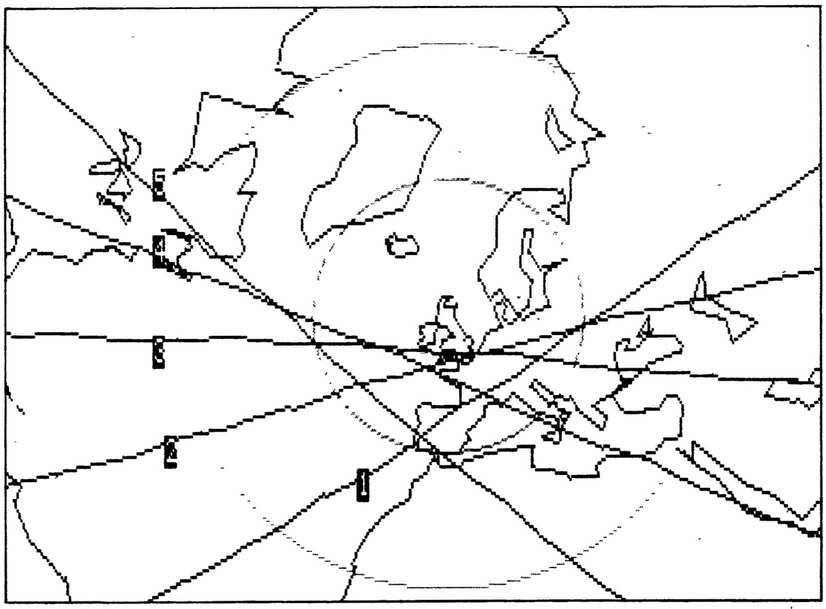
Start mid June late evening. End mid August
Start mid August, end late October 87
Start late October, end late December 87

Please note, however, that the Space Station may not be manned during the winter months.

Monitoring Procedure

The first requirement is to set up a simple dipole aerial and a VHF receiver, or, a converter to an FM, CB receiver, and then simply get used to listening to and tape recording the signals. It is important to record everything, whether the cosmonauts are talking or not. Every time the signal is present take a record, then when you play the tape back after the orbital pass

Fig. 1. Mir Space Station – typical series of orbits in range of UK.



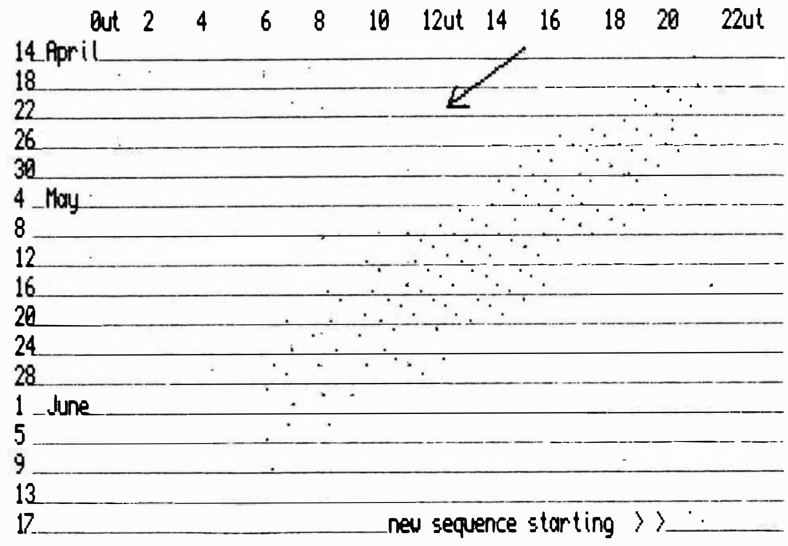


Fig. 2. Kettering plot of Mir space station orbits heard in UK, April to June 1987.

is over you will note that the gaps when no one is speaking often contain lots of other noises. Cosmonauts do not talk on every orbit, sometimes missing two or three successively, or worse still, only starting when deep into Soviet air space and about to fade below the UK horizon.

Listen carefully to the noises on the tapes. You should be able to pick out the steady hum of the ventilation fans and the rest of the air purification equipment as a steady almost constant background noise, and superimposed on this you will hear lots of other machines whose noise output is not steady. Some of the noises are cyclic repeating every 20 seconds or so, some are spasmodic, but all add to the general picture when the space station is fully operational. Indeed, it is when you do not hear these background noises that you can expect interesting things to happen.

In addition to the hum of the fans and the groans and shudders of the pipe work, the downlink also re-broadcasts several discrete radio signals. This situation arises because the cosmonauts usually listen to at least four other incoming radio uplink signals on loud speakers, and every time they broadcast on the downlink they re-broadcast whatever is coming out of their loud speakers.

By listening regularly, it will become easier to pick out these superimposed radio signals. The most commonly heard is the Russian Ground Conrol operator, whose speech is often re-broadcast for long periods when he is in conversation with the cosmonauts. Now and again a new voice will intrude, perhaps with a timing out of step with the normal orbital separation. This may lead to a change in the cosmonauts' flight schedule, with the communications ship having taken up that position in order to cover a vital part of an orbit or an experiment.

Voices can be compared from one tape to the next and newcomers can be easily identified, as can the equally important changes in voice quality of already identified personnel. Very often voice quality or procedure changes precede important mission changes. Only by acquiring a thorough knowledge of what the normal space station sounds like, does it become easy to identify important changes or omissions. The paragraphs which follow describe some of these changes and omissions, in the context of specific incidents.

Icecold Rescue

There have been many incidents and many surprises in the period 1985 to 1987and all could be detected from "sound clues" on the downlink.

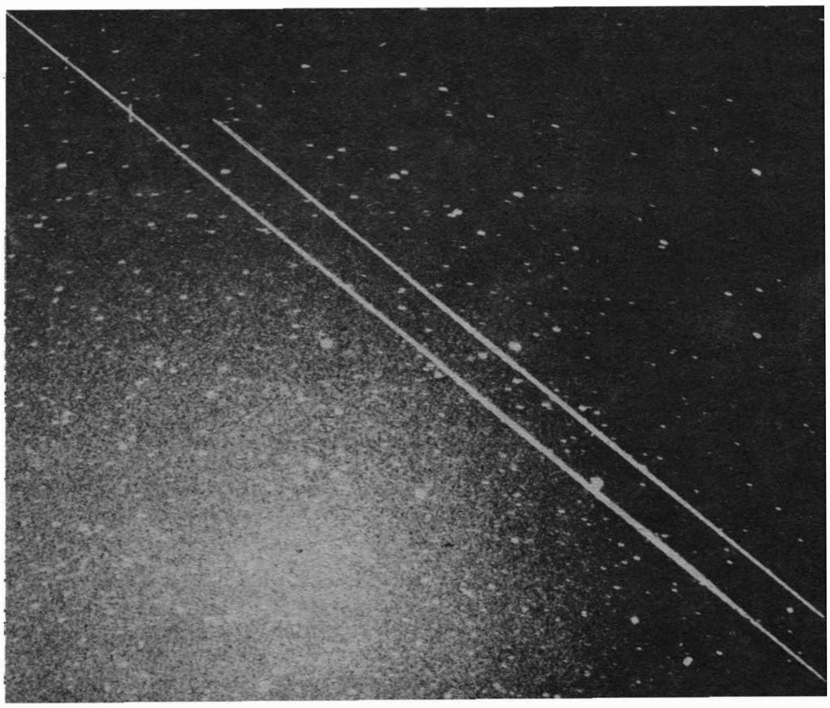
In June 1985 the Salyut 7 space station was the object of a special rescue mission. After some difficulty in aligning and docking with the errant space station cosmonauts entered and started to try to bring it back to life.

For several days they used only the 121.75 MHz downlink of their Soyuz ferry craft, for though the hatches between their craft and Salyut were open, the station was dead with no machinery noise whatsoever. Eventually the rescue party managed to organise enough electric power to realign Salyut's solar panels and start a battery charge, but it was some time before they had enough power to allow them to use Salyut's own 142.42 MHz downlink and the reason for this was very clear on their brief communications. The inside of the Salyut station was freezing cold. Any attempt at communications produced two effects, firstly the Cosmonauts breath froze as they spoke and hit the microphone with a rattle of ice particles and secondly opening their mouths to speak let in a draught of cold air which rapidly froze their vocal chords and swiftly terminated the conversation. It took more than a week for Salyut to be unfrozen and it was several more weeks before Salyut became truly habitable, with a full complement of machinery noise back on the downlink announcing that normal service had been restored.

Medical Emergency

In mid November 1985 the long stay crew in Salyut had a rather terse conversation with the "Zarya" (Dawn)

The Mir and Salyut 7 space stations captured in a single frame as they passed through the constellation of Draco over the skies of West Germany. One of the stations shows a distinct flash as it passes the star Eta Draconis The photograph was taken by ***D. Fischer*** during the Soviet 'space taxi' activities of mid-1986.



Ground Station Controller, followed by several exchanges using scrambled speech. For several days thereafter normal voice communications in plain language were resumed, but in all cases the exchanges were brief in the extreme. Then, on November 20, a new feature emerged as machinery noise began to disappear from the downlink background. Machines were clearly being shut down and left shut down. It was no great surprise therefore when the cosmonauts made no transmissions the next day and this surmise was confirmed 24 hours later (48 hours after the shut down started) when TASS announced that the mission had been terminated because of a medical emergency (***Spaceflight***, January 1986, p.19)

A New Space First

On May 5, 1986 the resident crew in Mir were strangely silent. Next day, as Salyut 7 passed over the UK with its attached Cosmos 1686 broadcasting loudly on its 19.955 MHz beacon, a second signal intruded using the Soyuz ferry frequency of 121.75. A quick check revealed that allowing for frequency difference the doppler curves of the Soyuz and the Space Tugs transmissions were the same. So they were very close or in touch, whereas Mir was still 10 minutes orbit time and nearly 3000 km to the West.

A very quick check of tape recordings soon established that this was not a new launch, the voices in the Soyuz were those of Kizim and Solovyev, the recent residents of Mir, who had now clearly moved over to Salyut.

Ninety minutes later this was confirmed when Kizim broadcast from Salyut on the 142.42 MHz downlink to announce their arrival. Apparently the station was cold and the cosmonauts returned to Soyuz for a warm night's sleep, checking communications from there before shutting down for the night. Next morning the cosmonauts started up Salyut's machinery and in the orbits which followed a good record of the switch-on and setting to work of the machinery was obtained.

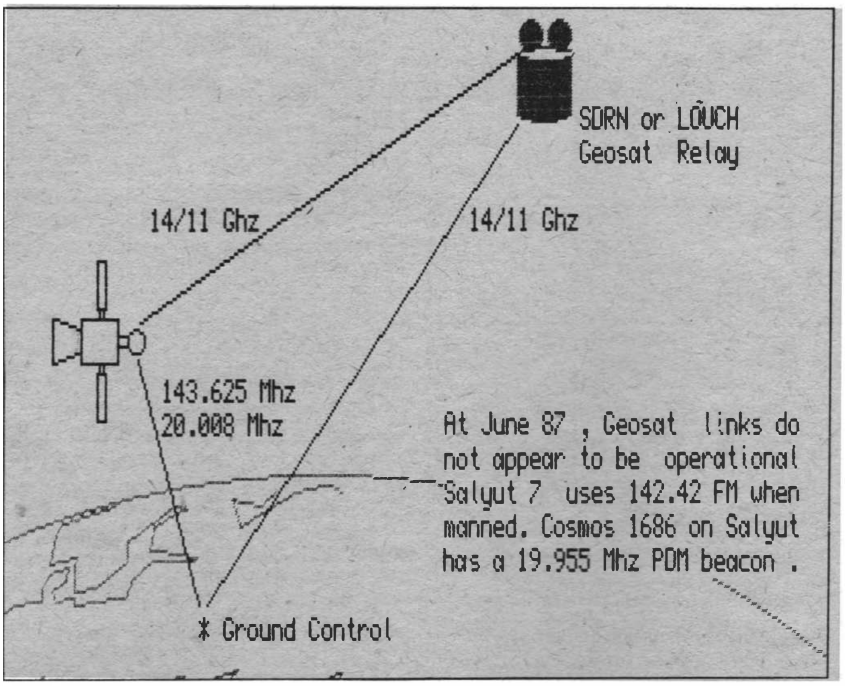


Fig. 3. Soviet space station communications links.

Monitoring EVA Activities

On the morning of May 31, 1986 Salyut was far to the east of the UK over Tyuratam when the 20.008 MHz HF downlink frequency came alive with cosmonaut chatter. For five minutes the signal was propagated to the UK via the ionosphere, with Kizim and Solovyev being audible with the now familiar gold fish bowl tones of men in space suits on EVA outside Salyut. Eighty minutes later the signal came up again as Salyut approached the UK, then as Salyut skimmed the UK's south east horizon, duplicate transmissions were audible on 121.75 and 142.42 MHz, a typical "Safety First" EVA communications feature.

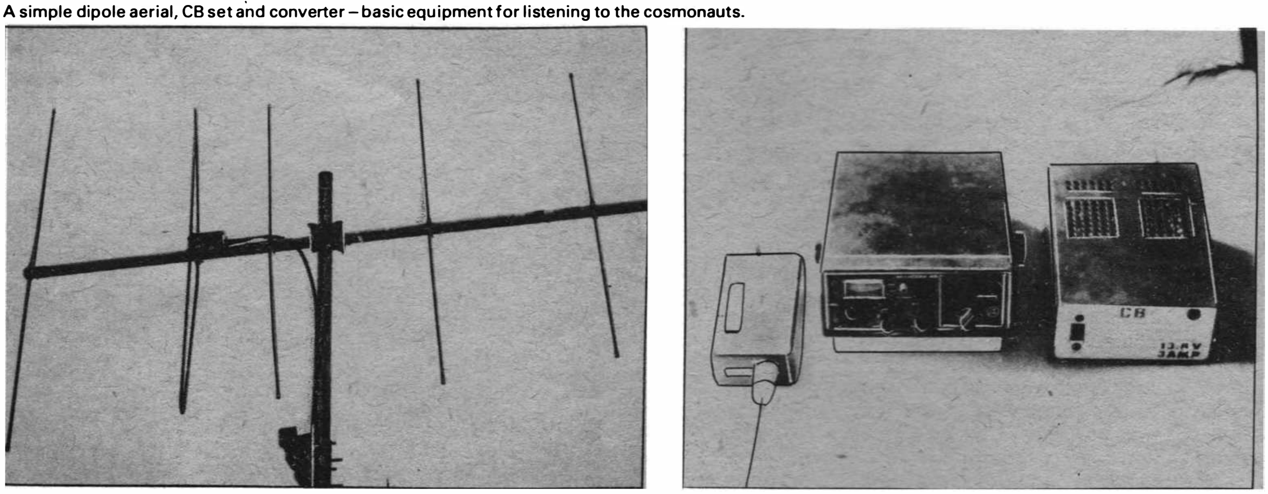
By the time that Salyut reappeared on its next in-range orbit the situation had changed. The bassy goldfish bowl speech had gone, but the relatively poor audio quality indicated that the two cosmonauts though back inside Salyut, were still in their space suits, and still using their space suit communications, albeit with helmets off.

Launch And Docking

Spacecraft launched from Tyuratam in Soviet Central Asia are out of range of UK stations on VHF, but they can sometimes be heard on an HF shortwave receiver via ionospheric propagation. The incident described below illustrates the sort of launch to docking communications a UK station may hear.

At about 1234 UT on March 13, 1986 Leonid Kizim and Vladimir Solovyev were launched from Tyuratam in Soyuz T 15 bound for the new Mir Space Station. This was announced as a long duration, 50 hour intercept and docking manoeuvre and the first signs heard in the UK were at about 1426 UT on the 13th when the 20.008 beacon

A simple dipole aerial, CB set and converter – basic equipment for listening to the cosmonauts.



was heard from Soyuz via ionospheric propagation. A signal to the UK from the mid-Pacific as this was, is not that unusual and happens regularly with other Soviet satellite signals propagated via the ionosphere. Later that day, at 1836 UT, the Soyuz beacon on 20.008 MHz was heard again in the UK, and this was followed almost immediately at 1840 UT by reception of the Soyuz VHF downlink voice channel on 121.75 Mhz.

On the following day only faint 20.008 Mhz beacon signals were heard as Soyuz passed near the UK,* but on March 15 at 1537 UT the 121.75 VHF signal was heard clearly as Soyuz docked with Mir. The two craft then proceeded to orbit together, with the 20.008 MHz being heard very strongly as it was switched on and off by the cosmonauts, until at 1839 UT the cosmonauts were heard for the last time on 121.75 VHF FM.

Next day the cosmonauts established communications on the standard Mir frequency of 143.625 MHz FM and thereafter that was the only VHF or HF frequency in general use. This pattern has been observed in several launch to docking sequences since 1984.

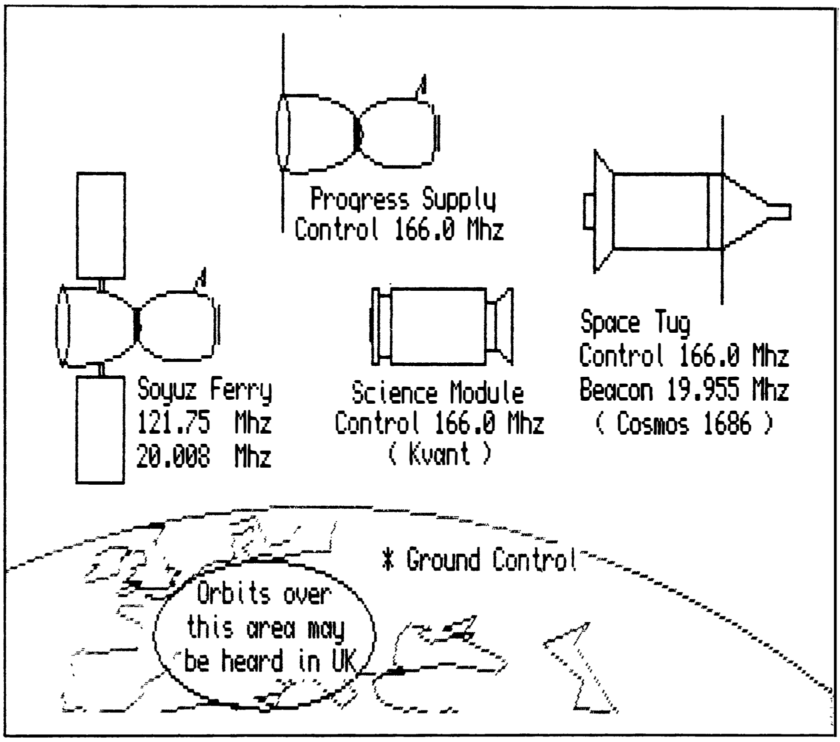


Fig. 4. Soviet support craft – communications and control facilities.

Data Links, Geosat Relays, Comships

In 1986 listeners to the VHF downlink from Mir regularly heard rebroadcasting of a series of tone signals and a pip tone sequence which had not been present in Salyut. These signals seemed to appear when Mir was connected to a geostationary relay satellite. When, in February 1987, a new pair of cosmonauts re-activated the Mir station, these extra signals were absent. Did this mean a geostationary problem?

At the beginning of March 1987 a second clue was added when the Mir cosmonauts were heard talking to someone on the Western side of the Atlantic somewhere near the Gulf of Saint Lawrence. Quite quickly the source of these signals, heard rebroadcast on the Mir downlink, was resolved as the Communications Ship Yuri Gagarin, moored in international waters off Sable Island, Nova Scotia, Canada. The use of a communications ship in this position was at variance with the availability of a geostationary relay covering the same (and a much greater) area. One or the other was superfluous, hinting that perhaps the geostationary relay was no longer operational.

This raised a further question mark. Mir was scheduled to receive a special Science Module. Most science modules produce masses of data and need wide band data links to large ground based computers. This type of link is only possible with a microwave geostationary relay, as the orbital dynamics and low-Earth orbit propagation problems operate against the use of a microwave channel direct from a low orbiter such as Mir, straight to the ground. So, given these technical imperatives, how would Mir operate its science module?

As yet the answer is not clear. However, there has been no lack of clues, noting that since late March 1987 the Mir downlink has been used normally to establish contact as the spacecraft entered Soviet air space. Then on several occasions, as soon as firm contact has been established, the VHF link has switched from voice transmission to high speed data transmission which continued as the spacecraft dropped below the UK eastern horizon.

Transmission modes have featured both Phase Shift Keying and a noise modulated mode only heard previously on Soviet military orbiters. As received in the UK these signals were not of a quality to support computer data transfer. This incident is therefore far from closed.

The Equipment You Need

There are various equipment packages available for listening to cosmonauts.

The simplest takes an old CB set, puts it on Channel 3 27.6225 MHz Frequency Modulated and connects to its aerial input a Microwave Modules Converter (MMC 144/28) available from Microwave Modules, Brookfield Drive, Aintree, Liverpool for £37.95. The converter is fed by a simple dipole aerial or any Radio Amateur 2 m 144 MHz aerial. It is fortuitous that this cheap converter is just right to convert Cosmonaut 143.625 to CB 27.625 approx.

If a Shortwave receiver which can receive FM (many cannot) is available it can be used with the same converter. Tuned to 27.625 it will receive Mir, and tuned to 26.420 it will receive Salyut if it ever re-opens, or perhaps more likely, use 142.42 for their Shuttle missions.

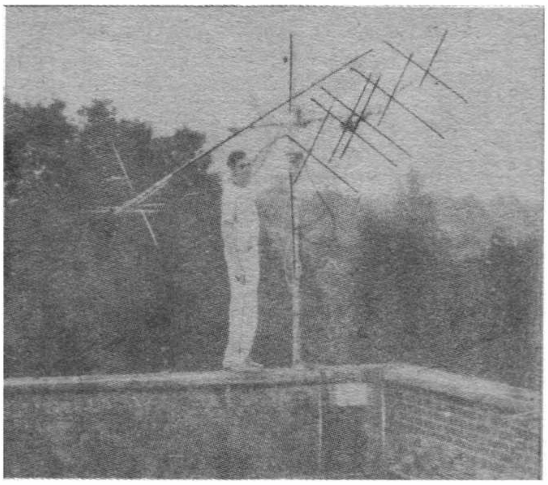
There are commercial VHF receivers available but they are expensive:

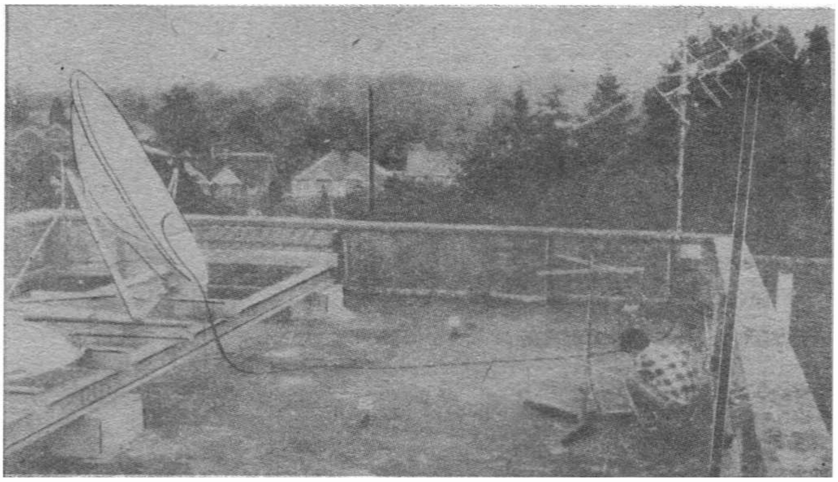
YAESU FRG 9600 costs £479 approx.
AR 2002 costs £459 approx.
ICOM R 7000 costs £859 approx.

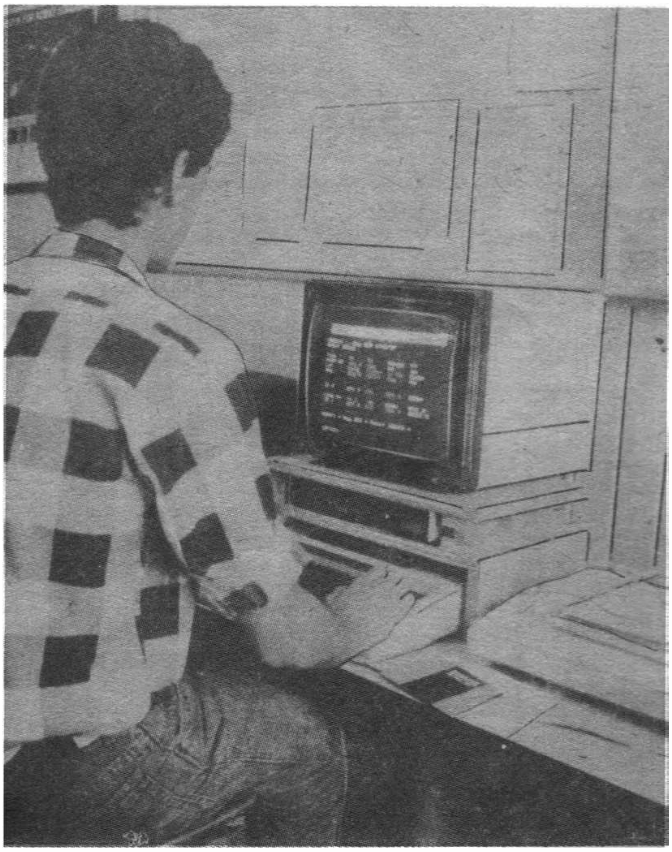
There are also Japanese Shortwave receivers fitted with their own VHF converters. Cost shown includes converter.

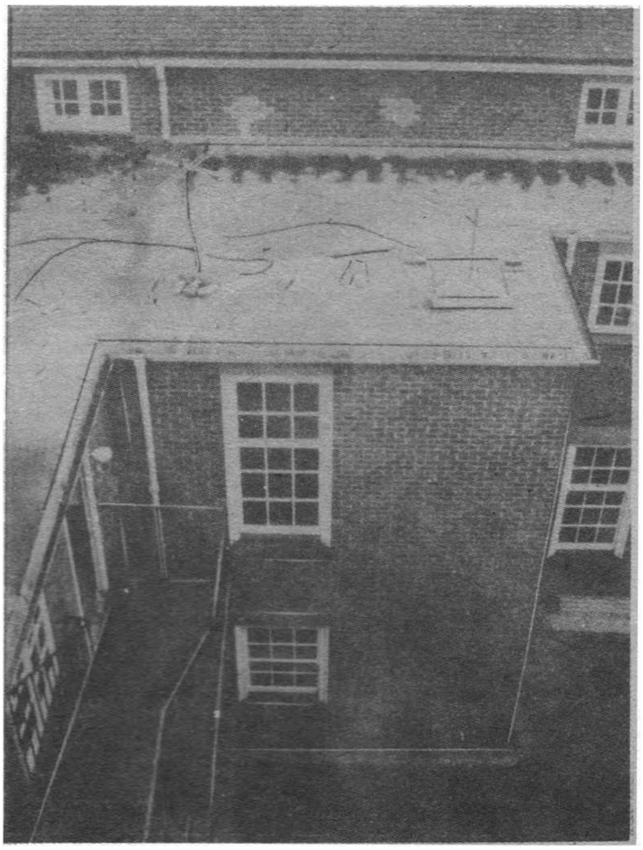
TRIO R 2000 costs £808.
YAESU FR 8800 costs £739.

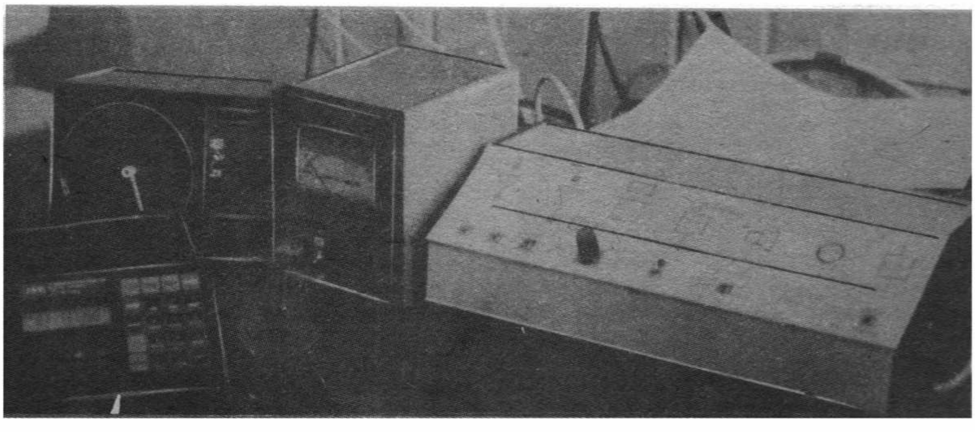
All this equipment receives a strong signal on a quite simple aerial. Big aerial beams are not advisable, small ones work fine.











Top left: Author pointing to the elevator and azimuth servo motors. The grey box on the inside of the parapet houses coaxial relays and pre-amps for UOSAT and NOAA. Both Yagi antennas are for UOSAT, the left hand one is part of the Unilab education equipment and the right is the original antenna connected to the scanning receiver. *Top right*: 2.2m dish receiving from Eutelsat F1. The A-level student is checking the weights holding down the omni-directional antenna for NOAA. *Above left*: Student operating BBC computer dedicated to satellite activities. *Above*: Two antenna on sub roof only slightly eclipsed by surroundings. The helical antenna is part of the Feedback weather satellite receiving system used to receive NOAA pictures. The antenna on the left, also for NOAA, is supplied with the Unilab satellite receiving equipment. *Left*: The control box on the right switches antenna connections and pre-amps to the scanning receiver (on left).

Industry Backs College Satellite Project

Colin Planterose, **head of Science at Godalming Sixth Form College, Surrey, England, describes the setting up of a satellite downlink system and its educational value.**

Introduction

In 1985 it was felt that a Satellite Downlink system was a practical proposition for the College to undertake. Information on the University of Surrey Satellite (UoSAT) was becoming more readily available and educational value could be seen in exploiting its output. Equipment needs were researched with the aid of books, magazines and a visit to a local radio ham's rig. The College was fortunate that at this stage the County Science Inspectorate agreed to provide £800 to buy a scanning receiver, two antennas, parts for a control box and coaxial cable. The scanning receiver system was installed and a control system constructed so that an omni-directional antenna (NOAA) or a Yagi antenna (UoSAT) could be switched into its input. Signals were quickly detected from many satellites.

Industry Lends A Helping Hand

Approaches were also made to several companies involved in space and electronics and the College began to receive offers of equipment on a gift or loan basis.

The first offer came from Precision Antennas who suggested that we might be able to use a 2.2 m parabolic dish. We visited the company and were shown two dishes and decided we could use both. The 2.2 m dish is now picking up signals from Eutelsat F2 and a smaller dish will be used for Meteosat. Precision Antennas kindly allowed us to use their design for a Meteosat feed. A student constructed it and the company then tuned it to the correct frequency. The output from the feed connects to the scanning receiver via a downconverter. This unit was funded by British Aerospace.

The College then took up the offer made by Racal Decca of the long-term loan of a complete weather satellite receiver system. This proved particularly attractive since almost instantly we were obtaining weather pictures from NOAA and, a little later, pictures from Meteosat 2. The delay with the latter was due to a fault in the downconverter of the receiving system. This was put right by an engineer from Marconi Space Systems.

A Marconi electronics engineer helped with the College system as part of the company's contribution to Industry '86 Year. The scanning receiver system then acquired its own BBC computer, courtesy of British Petroleum and a disc drive from Cumana.

Towards the end of 1986 an approach was made to Sat-Tel to help with a satellite TV receiver. The receiver, together with a polarising switch, duly arrived and negotiations with the Science Inspectorate and County Hall produced a low noise converter and a three tonne steel-and-concrete antenna support system for the College roof.

The systems installed to date and departments concerned are:

1. Scanning receiver, omni-directional antenna, Yagi antenna, BBC computer system (Physics and Electronics).
2. Feedback Systems Weather Satellite Receiver system (Physics and Geography).
3. 2.2 m dish, Satellite TV receiver (Foreign Languages).
4. 1.8 m dish, downconverter (Physics, Geography, Computer Science).

The emphasis during the first two years has been upon the acquisition of equipment, setting it up and learning how to use it. It has been the responsibility of the staff to obtain equipment but it was the policy from the start to involve students in setting it up. In practice, students have rapidly come to grips with the techniques needed for receiving and processing satellite signals and often provided instruction for the staff!

Soviet Navigation Satellites

During these two years students have worked on four projects. One, which has taken two years for completion, is the reception, electronic decoding and computer processing of signals from Soviet navigation satellites. The project, based on a paper by Geoffrey Perry, involved original work on an electronic decoder and computer software. The system is now able to output the satellite's position and velocity in real time from the information broadcast by the satellite. The next stage will be to measure the Doppler shift frequency and so obtain the range at closest approach, enabling the position of the receiver to be calculated. Hopefully, the whole system will eventually operate in real time as in a professional satellite navigation unit.

Weather Pictures

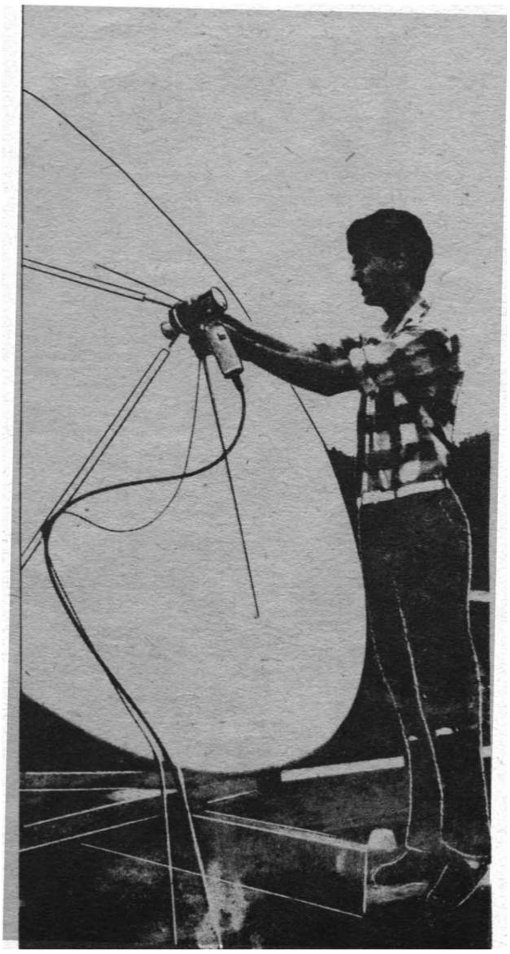
Another completed project involves software for a Meteosat Picture Sequencer. Meteosat, a geostationary satellite positioned at 0 degrees longitude, 35,000 km above the Earth, 'sees' a complete view of one half of the Earth. In practice it broadcasts the complete view only occasionally as part of a sequence of pictures. The other views are sub-divisions of the complete scene. Furthermore the pictures are of two types, visible and infrared.

The sequencer allows a particular type of picture to be extracted from the sequence. It is digitised by a commercial piece of electronics and then saved on floppy disc. When the next picture is transmitted the process is repeated.

About 30 pictures can be stored and then played back so that when viewing the monitor screen they scroll into each other in a cartoon-like fashion. The sequence can be videoed and a permanent record of a weather pattern over, for example, 24 hours obtained. The second part of this project is the software to clean up the pictures. This removes random dots and the sequences then show only the movement of patches of continuous dense cloud.

The above system, although flexible, is only able to cope with a limited number of grey levels. This severely limits the quality of the recorded pic-

The 2.2m dish which receives information from Eutelsat FI and provides the college's foreign languages department with French German and Italian TV programmes



tures. Photographic printing paper, of course, produces a complete range of grey levels and so there is a real advantage in producing hard copy pictures on this type of paper. However, students first had to construct a light source able to follow the variations of the signal from the satellite and to produce light to which bromide paper is sensitive. Unfortunately LEDs emitting bright blue light, the colour necessary, are not available at present and a more complicated electromechanical arrangement had to be constructed. This light source together with a converted stencil cutter should in the future allow the production of weather pictures on bromide paper.

Antenna Control

Another project to mention is the design and construction of the computer control of the Yagi antenna. This will now, under software control, follow a satellite as it crosses the sky. The downlink project is proving a rich source of project work and an A-level Design and Technology student has decided to design a dish steering system to increase the number of TV channels it is possible to receive.

Course Developments

The emphasis is now changing. The hardware and software that we have, allows us to receive signals from a large number of satellites – but how is all this to be used educationally? Apart from individual projects, satellite work has been available as a General Studies course. The course started essentially as a practical activity but has now become a more formal course consisting of a series of lectures with some practical work included. The course is titled Space Science.

Good satellite receiving equipment has, within the last year, become available from education equipment suppliers and the four schools which provide students for Godalming Sixth Form College now have their own independent downlink systems. Our group will over the next year or so be developing curriculum material suitable for children from the third year upwards. We are considering the possibility of a Space Science module in the new GCSE exams and the forthcoming AS level (half an A-level). We are also in contact with the National Resource Centre for Satellites in Education (NRCSE) and the UoSat Office, both based at the University of Surrey. Via ***Spaceflight*** magazine we have begun to liaise with the Center for Aerospace Education in St. Louis, Missouri (USA). We would like to set up links with groups in other countries. An interesting project for such a linked group could be packet radio which recently became available on UoSAT 2.

Conclusion

The educational value of Space Science is enormous. It is relevant to Physics, Electronics, Computing, Mathematics, Design Technology, Geography and Foreign Language departments. Space Science provides useful examples, projects and services. Readers will be aware of the change in the Space Science scene from a strictly science/technology emphasis to one which is becoming important for its industrial value. Education should attempt to reflect this change.

US Shuttle Astronaut's Lecture Tour

Colonel Bolden, a member of the Marine Corps before training as an astronaut in 1980, has undertaken numerous assignments for NASA and was the pilot of a January 1986 Space Shuttle mission. He has logged 146 hours in space.

NASA Astronaut Colonel Charles Bolden received an enthusiastic response from audiences during a series of summer lectures in London.

The tour, organised by South Bank Polytechnic, ended with a lecture to industrialists and educationalists entitled "Space: Past, Present and Future" after talks to various groups of London school children and students. He succeeded in charming all his audiences with tales of his experiences in space, from the problems of weightlessness and showering in the US space shuttle to questions of diet, comfort and the beauty of the Earth as viewed from space. He also talked about the effect of last year's Challenger disaster on the future of the space programme.

The visit, supported by Inner London Education Authority, the Wellcome Foundation, the Royal Society of Chemistry, IBM and the Royal Navy, was intended to emphasise the value of science and technology in education and the need to develop strong links between the academic world and industry.

Acknowledgement

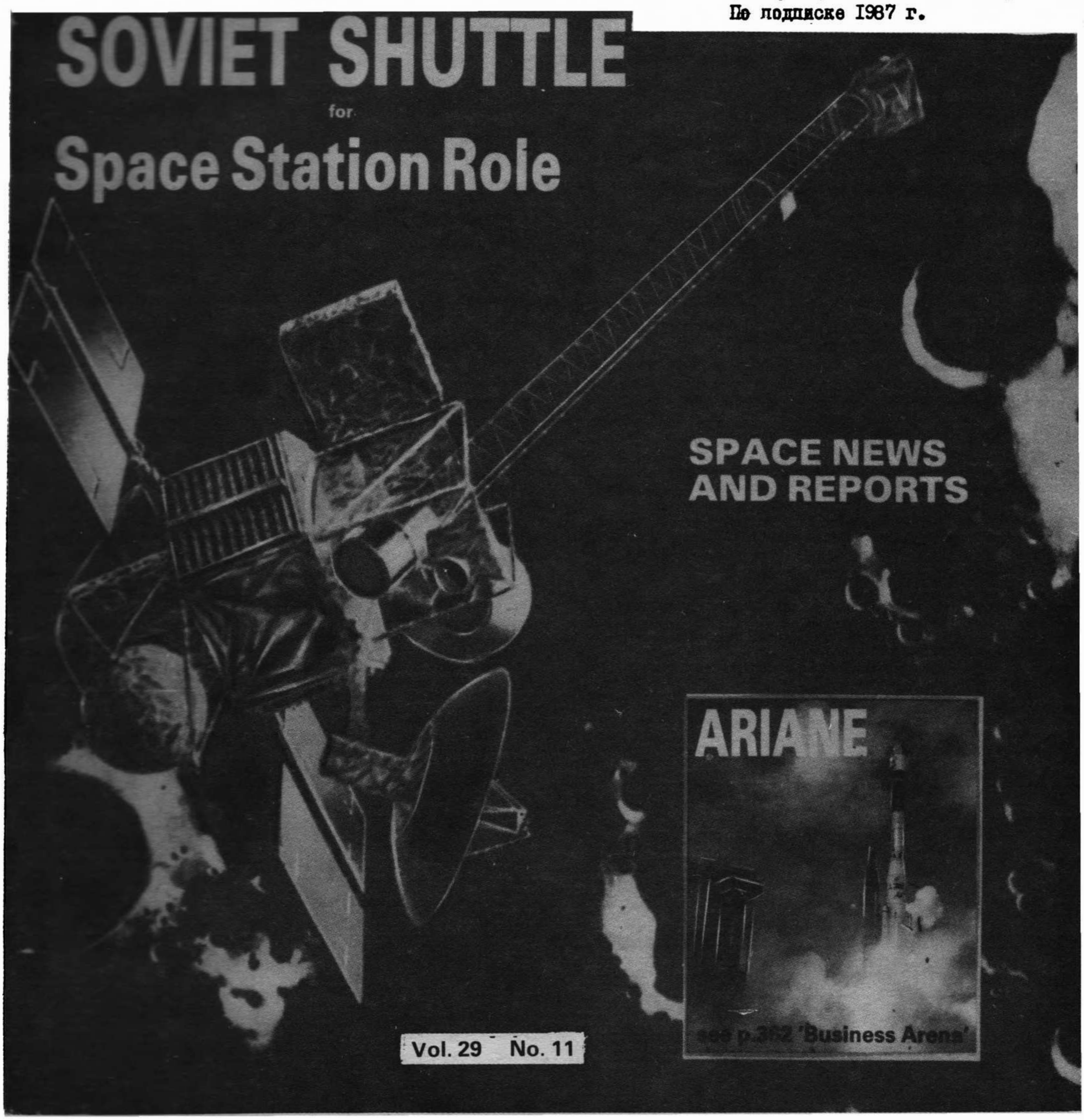
An illustration on p.7 of ***Spaceflight*** Supplement No. 1, July 1987, should have contained an acknowledgement to C.P. Vick on whose work the Soviet Shuttle drawing was partially based.

In preparing the illustration for ***Spaceflight*** alternative information was also used by the author for which reason it differs from that published in the *National Geographic* magazine, October 1986, p.452.

NOVEMBER 1987 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics



Spaceflight

The International Magazine of Space and Astronautics

Vol. 29 No. 11 November 1987

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27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22-26 Farringdon Lane, London EC1R 3AU. Tel: 01-253 3135.

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L. Ltd., Aylesbury, Buckinghamshire, England.

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Front Cover: An artist's conception of the Lunar Geoscience Observer which is proposed for the 1990's to map the lunar surface, perform geochemical studies and search for water in the lunar polar regions. Such data would be invaluable for deciding on the location of a lunar base. See p.346 for this issue's special feature 'Towards a Lunar Base'.

Outpost on the Moon

"The US civilian space programme is now at a crossroads, aspiring toward the visions of the National Commission on Space but faced with the realities set forth by the Rogers Commission. NASA must respond aggressively to the challenges of both while recognising the necessity of maintaining a balanced space programme within reasonable fiscal limits.

"We must ask ourselves: 'Where do we want to be at the turn of the century?' and 'What do we have to do now to get there?' Without an eye toward the future, we flounder in the present. It is now too early to crystallise our vision of the space programme in the year 2000. A clear vision provides a framework for current and future programmes: it enables us to know which technologies to pursue, which launch vehicles to develop, and which features to incorporate into our Space Station as it evolves."

Sally K. Ride, the first US woman astronaut, who led the preparation of the report to NASA on "Leadership and America's Future in Space".

These stirring words preface Sally Ride's farewell report to NASA entitled "Leadership and America's Future in Space", which selects four bold initiatives "to energise a discussion of long-range goals and strategies for the civilian space programme". One of these is for an 'Outpost on the Moon' which would build on the legacy of Apollo and lead to a new phase of lunar exploration and development. The outpost would support scientific research and exploration of the Moon's resource potential, and would represent a significant extraterrestrial step toward learning to live and work in the hostile environments of other worlds.

Beginning with robotic exploration in the 1990s, this initiative would land astronauts on the lunar surface in the year 2000, to construct an outpost that would then evolve in size and capability.

The intention of the Ride report is not to choose one initiative and discard the other three, but rather to study the four candidate initiatives and put them forward for further discussion. It assesses an 'Outpost on the Moon' in the following way.

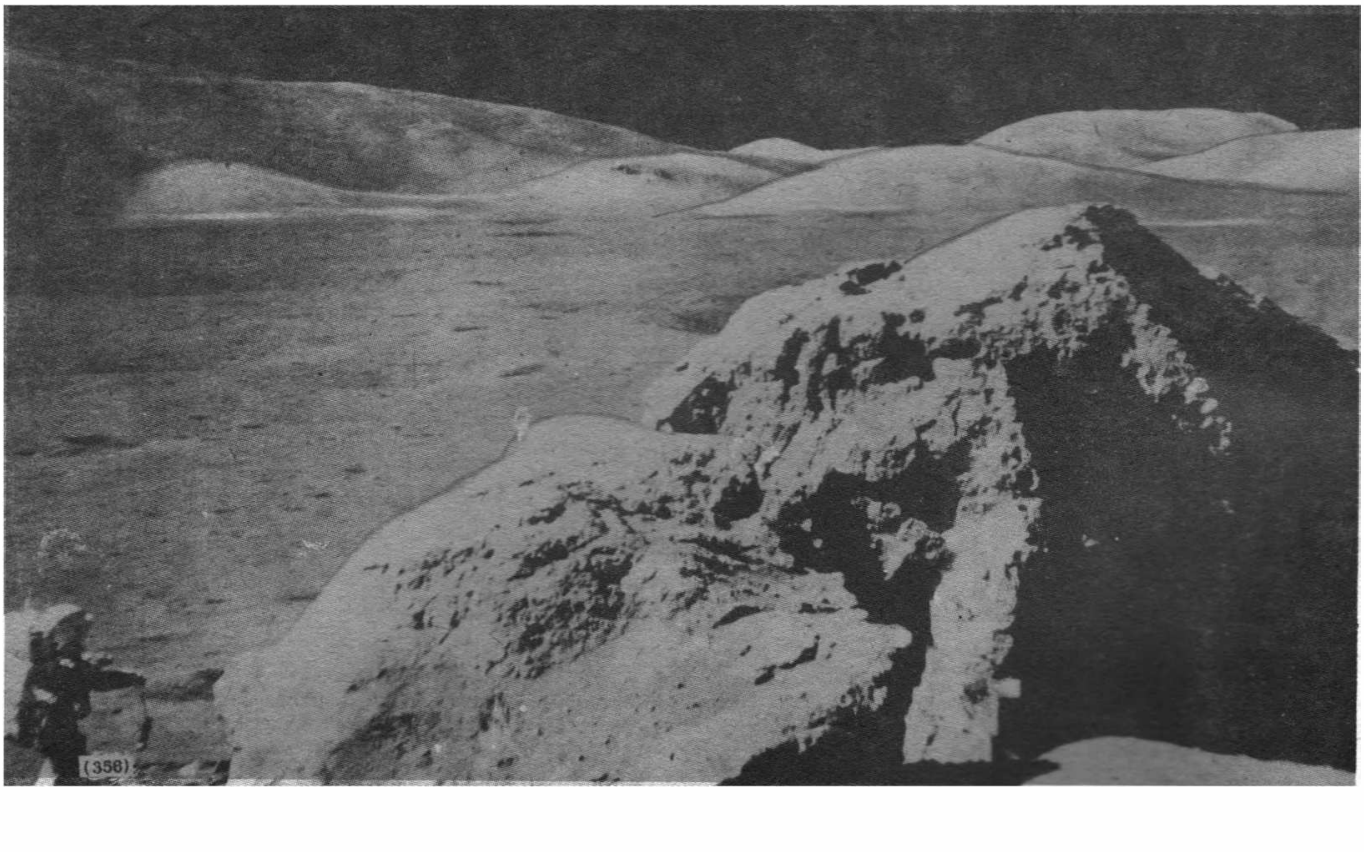
Background

The Apollo Programme was a great national adventure. We sent explorers to scout the cratered highlands and smooth maria of the Moon, and to bring samples collected on their trips back to laboratories on Earth. The world was fascinated by the Apollo missions and the information they obtained, and the samples provided scientists many exciting clues about the Moon's origin and chemical composition.

The Apollo era ended 15 years ago, before we could fully explore the promise of lunar science and lunar resources. But we learned that human beings can work on the surface of the Moon and we laid the technical foundation to develop the scientific and engineering tasks for the next stages of exploration. This initiative would send the next generation of pioneers – to pitch their tents, establish supply lines, and gradually build a scientifically and technically productive outpost suitable for long-term habitation.

This initiative represents a sustained commitment to learn to live and work in space. As our experience and capabilities on the lunar surface grow, this extraterrestrial outpost will gradually become less and less dependent on the supply line to Earth. The first steps toward "living off the lunar land" will be learning to extract oxygen from the lunar soil, where it is plentiful, and learning to make construction materials. The lunar soil would eventually

Apollo 17 was man's last visit to the Moon during which nearly 400 kg of lunar rock was brought back and over 50 scientific experiments were placed on the surface. In this photograph, Harrison Schmitt, who was a geologist, inspects a large boulder in the Taurus-Littrow area of the Sea of Serenity, around which he and Gene Cernan drove in the lunar rover, covering 22.5 miles.



be a source of oxygen for propellant and life-support systems, and a source of material for shelters and facilities.

The Moon's unique environment provides the opportunity for significant scientific advances; the prospect for gains in lunar and planetary science is abundantly clear. Additionally, since the Moon is seismically stable and has no atmosphere, and since its far side is shielded from the radio noise from Earth, it is a very attractive spot for experiments and observations in astrophysics, gravity wave physics, and neutrino physics, to name a few. It is also an excellent location for materials science and life science research because of its low gravitational field (one-sixth of Earth's).

Strategy and Scenario

This initiative proposes the gradual, three-phase evolution of our ability to live and work on the lunar surface.

Phase I: Search for a Site (1990s)

The initial phase would focus on robotic exploration of the Moon. It would begin with the launching of the Lunar Geoscience Observer, which will map the surface, perform geochemical studies, and search for water at the poles. Depending on the discoveries of the Observer, robotic landers and rovers may be sent to the surface to obtain more information. Mapping and remote sensing would characterise the lunar surface and identify appropriate sites for the outpost. The discovery of water or other volatiles would be extremely significant, and would have important implications for the location of an habitable outpost.

Phase II: Return to the Moon (2000-2005)

Phase II begins with the return of astronauts to the lunar surface, (see Figure 1). The initiative proposes that a crew be transported from the Space Station to lunar orbit in a module propelled by a lunar transfer vehicle. The crew and equipment would land in vehicles derived from the transfer vehicle. Crew members would stay on the surface for one to two weeks, setting up scientific instruments, a lunar oxygen pilot plant, and the modules and equipment necessary to begin building a habitable outpost. The crew would return to the orbiting transfer vehicle for transportation back to the Space Station.

Over the first few flights, the early outpost would grow to include a habitation area, a research facility, a rover, some small machinery to move lunar soil, and a pilot plant to demonstrate the extraction of lunar oxygen. By 2001, a crew could stay the entire lunar night (14 Earth days), and by 2005 the outpost would support five people for several weeks at a time.

Phase III: At Home on the Moon (2005-2010)

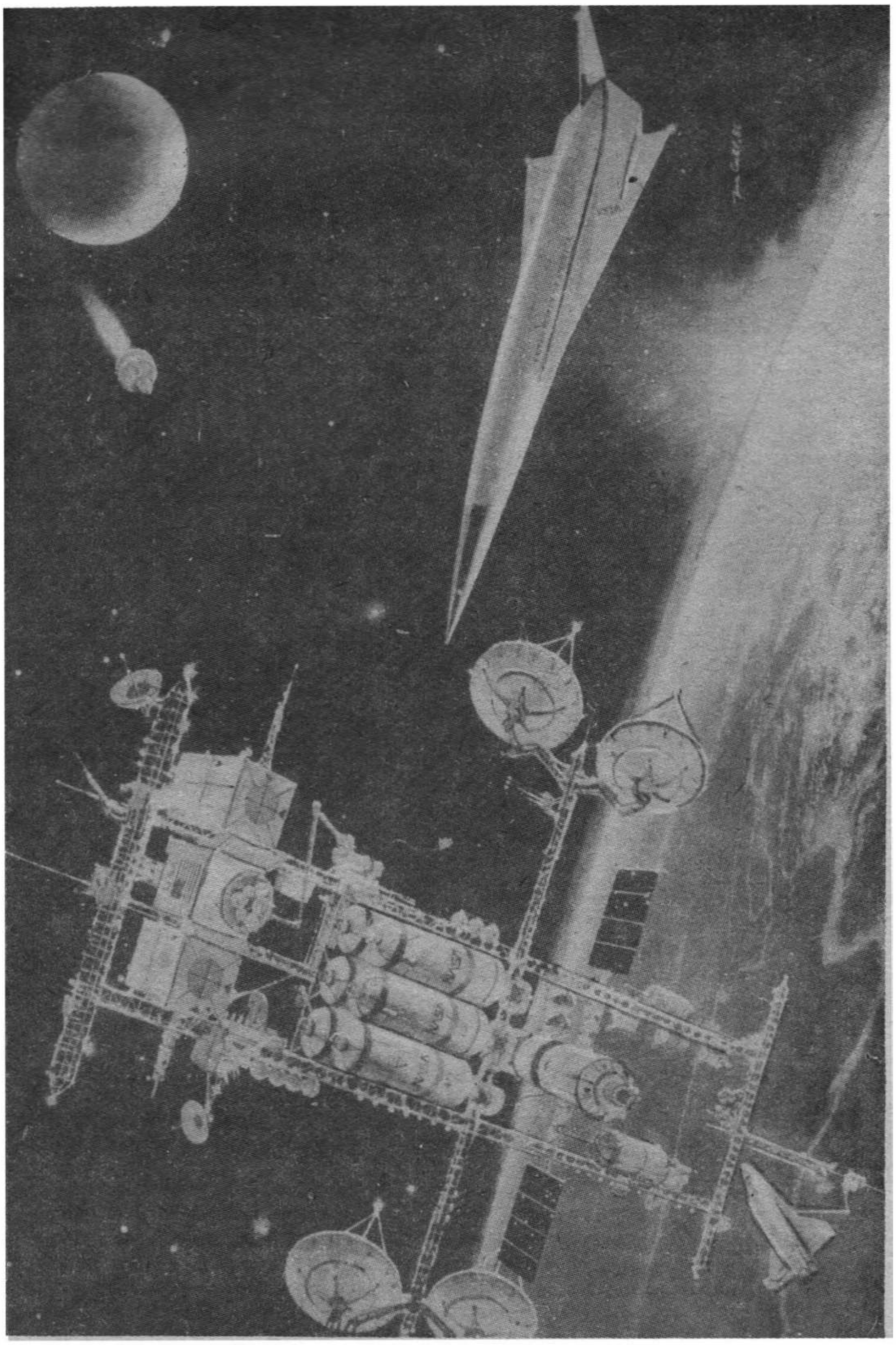
Phase III evolves directly from Phase II, as scientific and technological capabilities allow the outpost to expand to a permanently occupied base. The base would have closed-loop life-support systems and an operational lunar oxygen plant, and would be involved in frontline scientific research and technology development. The programme also requires the mobilisation of disciplines not previously required in the space programme: surface construction and transportation, mining and materials processing.

By 2010, up to 30 people would be productively living and working on the lunar surface for months at a time. Lunar oxygen will be available for use at the outpost and possibly for propellant for further exploration.

Transportation, Orbital Facilities

This initiative envisions frequent trips to the Moon after the year 2000 – trips that would require a significant investment in technology and in transportation and orbital facilities in the early 1990s.

The critical technologies for this initiative are those which would make human presence on the Moon meaningful and productive. They include life-support system technologies to create an habitable outpost; automation and expert systems and surface power technologies to make the out-



A spaceport in Earth orbit receives supplies from a cargo transport vehicle (lower right). In the distance a two stage transfer vehicle is returning from the Moon. © *Robert McCall*

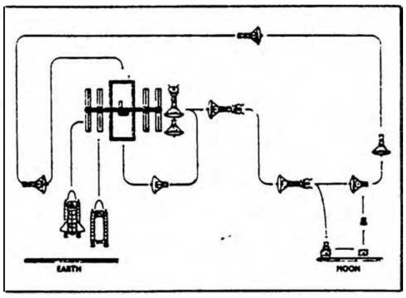


Figure 1. Scenerio for return to Lunar surface; Piloted Sortie, Expendable Lander.

post functional and its inhabitants productive; and lunar mining and processing technologies to enable the prospecting for lunar resources.

The transportation system must be capable of regularly transporting the elements of the lunar outpost, the fuel for the voyage and the lunar crew to low-Earth orbit. This requires a heavylift launch vehicle and a healthy space shuttle fleet. The transfer of both cargo and crew from the space station to lunar orbit requires the development of a reusable space transfer vehicle. This and a heavy-lift launch vehicle will be the workhorse of the Lunar initiative.

The space station is an essential part of this initiative. As the lunar outpost evolves, the space station would become its operational hub in low-Earth orbit. Supplies, equipment and propellants would be marshalled at the station for transit to the Moon. It is therefore required that the space station evolve to include spaceport facilities.

In the 1990s, the Phase 1 space station would be used as a technology and systems test bed for developing closed-loop life-support systems, automation and robotics, and the expert systems required for the lunar outpost. The outpost would, in fact, rely on the space station for many of its systems and subsystems, including lunar habitation modules which would be derivatives of the space station habitation/laboratory modules.

Evaluation

The Lunar initiative is a logical part of a long-range strategy for human exploration. The National Commission on Space recommended that the USA follow a "natural progression for future space activities within the Solar System," and concluded that the natural progression of human exploration leads next to the Moon (***Spaceflight***, May 1986, p.194).

The establishment of a lunar outpost would be a significant step outward from Earth – a step that combines adventure, science, technology, and perhaps the seeds of enterprise.

Exploring and prospecting the Moon, learning to use lunar resources and work within lunar constraints, would provide the experience and expertise necessary for further human exploration of the Solar System.

The Lunar initiative is a major undertaking. Like the Mars initiative, it requires a national commitment that spans decades. It, too, demands an early investment in advanced technology, Earth-to-orbit transportation, and a plan for space station evolution. Even considering its gradual evolution over the first five years, the ambitious build-up of the lunar outpost envisioned in this scenario would require a high level of effort in the mid-to-late 1990s and would place substantial demands on transportation and orbital facilities. This is a period when resources may be scarce.

However, this initiative is quite flexible. Its pace can be controlled, and more important, adapted to capability. It is possible to lay the foundation of the outpost in the year 2000, then build it gradually, to ease the burden on transportation and space station at the turn of the century.

The Lunar initiative is designed to be evolutionary, not revolutionary. Relying on the space station for systems and subsystems, for operations experience, and for technology development and testing, it builds on and gradually extends existing capabilities. Many of the systems needed for reaching outward to Mars could be developed and proven in the course of work in the Earth-Moon region. It is not absolutely necessary to establish this stepping stone, but it certainly makes sense to gain experience, expertise and confidence nearer Earth first, and then to set out for Mars.

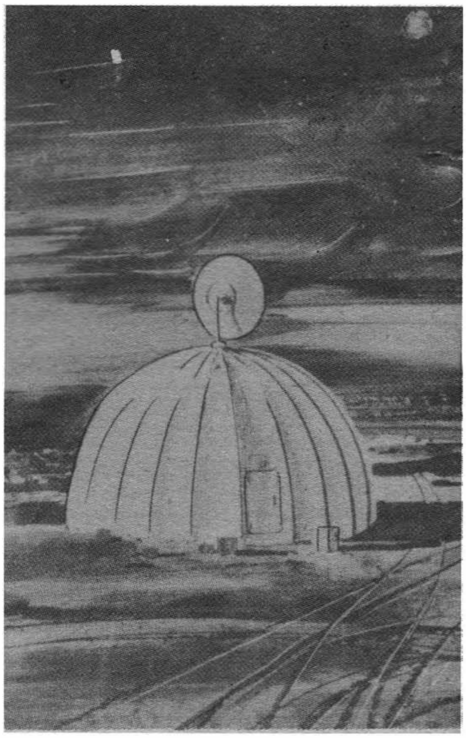
This study did not include an assessment of the level of public support for these initiatives. However, there is considerable sentiment that Apollo was a dead-end venture, and we have little left to show for it. Although this task force found some who dismissed this initiative because "we've been to the Moon", it found many more who feel that this generation should continue the work begun by Apollo.

Although explorers have reached the Moon, the Moon has not been fully explored. This initiative would push back frontiers, not to achieve a blaze of glory, but to explore, to understand, to learn and to develop; it would place the Apollo Programme into a broader context of continuing exploration, spanning several generations of Americans. And it fits beautifully into a natural progression of human expansion that leads "from the highlands of the Moon to the plains of Mars".

"Although explorers have reached the Moon, it has not been fully explored. This initiative would push back frontiers, not to achieve a blaze of glory, but to explore, to understand, to learn and to develop."

Supercondu

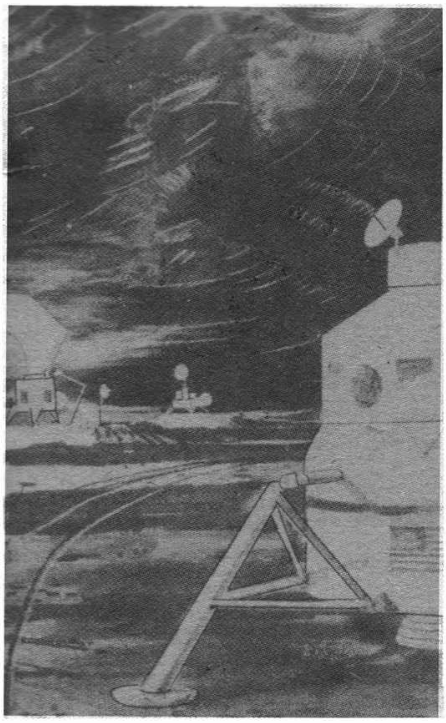
by A.T. Lawton and Penny Wright



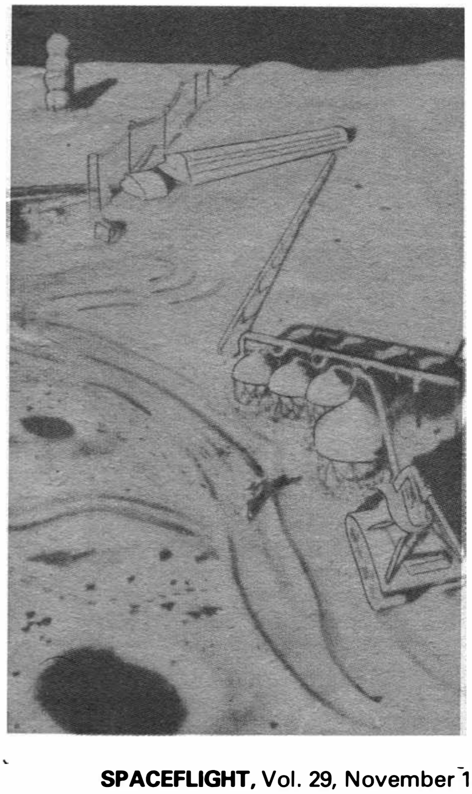
The start of manned operations at a Lunar Polar Base (above). In the middle distance at the centre right is an automatic processing plant designed to extract oxygen from local rocks in a furnace heated by concentrating the rays from a low-altitude Sun. .IPI

uctors Lift Lunar Base Prospects

New superconducting ceramics promise to revolutionise electrical and electronic technology on Earth but even greater potential could be realised in applications to Lunar Base technology. Superconducting ceramics could be made from lunar rocks with the cooling necessary for their operation being derived naturally from the wide temperature variations of the lunar surface. This article outlines the basic technology of these cost-saving techniques and some of the anticipated future lunar applications.



Lunar operations (below) involving the production of liquid oxygen by the mining of ilmenite. A loader transports useable material to a furnace in the upper centre of the picture. The oxygen is liquified and stored in the containers on the right.
NASA



Superconductors

Most people are familiar with the concept of electrical conductivity – electric currents being carried by metallic wires of copper, aluminium or other metallic alloys. They are also familiar with these wires becoming warm if they carry a heavy current – a property known as electrical resistance. This property is carried to extremes in the red heat of an electric radiator fire and in the white heat of an incandescent filament in an electric light bulb.

Less well known is that some metals and alloys lose their electrical resistance altogether under special conditions. An electric current caused to circulate through a ring or coil of such material would do so for ever – simply because there are no losses involved [1]. It is the closest realisation of the old Victorian dream of perpetual motion, and many research laboratories throughout the world have apparatus where the current has been circulating for *years* – providing the temperature is kept sufficiently low.

And there lies the major snag! Although known for nearly a century, most of the materials available today exhibit superconduction at temperatures close to Absolute Zero and have to be continuously immersed in liquid helium (temperature 4.3 K). A few specialised alloys (based largely on niobium, tin, zirconium and trace metals) will exhibit commercially useful superconduction at the higher temperature of liquid hydrogen (20.4 K). See Table 1. Storage of liquid hydrogen on the Moon could be much easier than storage on Earth – but lunar hydrogen appears to be absent either as hydrides in rocks or as water. Future expenditions may find ice trapped deep in lunar chasms or craters – but the general outlook is that hydrogen on the lunar surface is scarce or absent. Exploitation of superconductivity on the Moon therefore seemed to be a complete non-starter, and this situation continued up to 1987.

The New Superconductors

The above explains why the newly discovered superconductor ceramics offer such tantalising possibilities [2]. Firstly they behave as superconductors at very much higher temperatures than all previously known materials, and can be operated at the temperature of liquid nitrogen (77 K). Further developments have now allowed operation at liquid oxygen temperatures (90 K) and liquid oxygen is widely accepted as one of the first materials to be made from lunar rocks once a lunar base is established. In this outline article we therefore suggest that the use of superconducting powerlines made from native lunar ceramics derived from lunar rock and naturally cooled in a manner (later described) is a realistic 21st century possibility. This means there is no need to resort to metallic conductors with their associated losses when setting up a lunar power grid.

We recognise that more detailed research will be necessary to quantify the actual processes and economics thereof, but already there is steadily accumulating evidence that superconducting ceramics are here to stay. Even high school students can make them [3].

What are these new materials? As mentioned earlier the original superconductors were metals or alloys some of which are listed in Table 1. These new materials are based on oxides of rare Earth metals such as lanthanum, yttrium and europium mixed with commoner materials such as barium oxide and copper oxide. Some workable combinations are listed in Table 2.

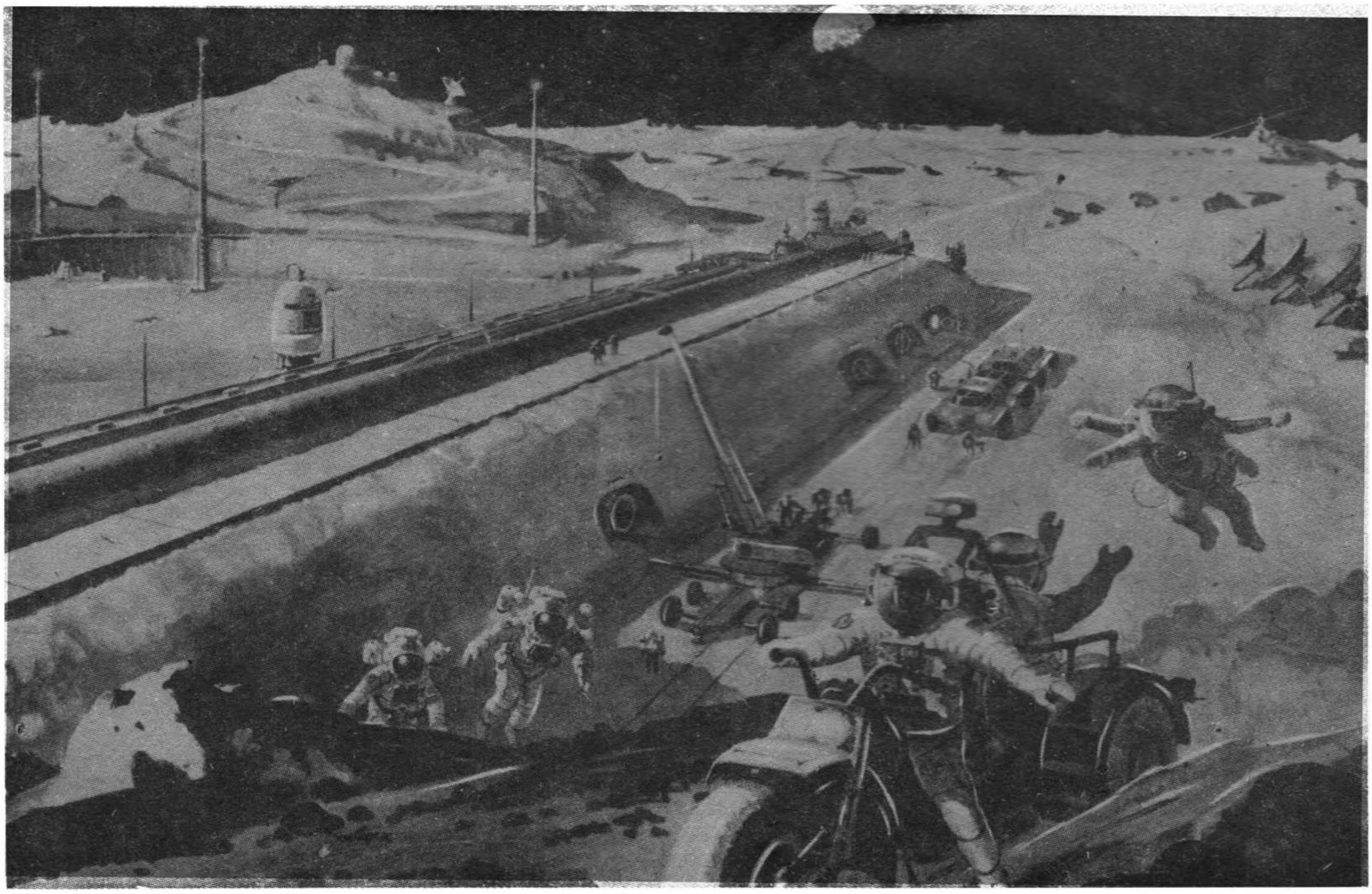
Lunar Applications

Some areas of the Moon will require large quantities of electrical power a considerable distance away from where it is most efficiently generated. This could arise where useful quantities of metal bearing rocks and ores are sited several hundred (or thousands) of kilometres away from the solar cell or solar boiler electrical

Table 1: Historical Conventional Superconduction Materials.

Metal or Alloy	Superconducting Temperature (K)	Critical Flux (Gauss)
Lead	7.26	600 *
Mercury	4.12	14 *
Tin	3.69	50 *
Aluminium	1.14	– *
Zinc	0.79	– *
Cadmium	0.6	– *
Niobium – Tin	20.4	200×10^3 †
Niobium – Titanium	19.1	

* *Kamerlingh Onnes, Ref. 1, 1911*
† *Typical modern (1950-1980) Alloys*



Lunar activities in the 21st century could include astronomy, both optical and radio wave, and the use of material to manufacture products in space. In the foreground, a mass driver is propelling pieces of lunar material into Space. *© Robert McCall*

generating station. Electricity will be required to reduce these ores. Typical examples of metals produced by electrolysis are aluminium, titanium, magnesium – all are found in Moon rocks. To generate the electricity locally may not be possible and to use copper or aluminium cables of any great length would involve considerable losses.

Using superconduction cables the problems are avoided and by careful design the Moon itself can provide the necessary cooling.

Furthermore these cables could be made from Moon rock materials. The basic elements required are:

europium	*trace elements only*
yttrium	*trace element only*
lanthanum	*trace element only*
barium	*fraction element*
copper	*bulk element*
gold	*fraction element*
oxygen	*bulk element*

Gold has been successfully used to bind the superconducting ceramic crystals into a matrix which permits the drawing of the material into ribbon, tape, or wire without detriment to the superconducting properties of the basic material [4].

Lunar Cooling of Superconductors

During a lunar day the surface at the Moon's equator achieves a temperature of 400 K (130°C). During the lunar night the temperature drops to around 73 K (-200°C). A region not receiving any direct sunlight is likely to remain *permanently* around 73 K (-200°C), ie well below the freezing point of water at normal Earth atmospheric pressure [5].

Thus, if the ceramic superconducting cables or conductors are housed in deep "troughs" which are open to the sky, then the cable will only "see" a temperature close to that of space itself (3 K). Obvious losses and stray reflections will raise this considerably, but there is a strong possibility that stable temperatures of between 80 K and 90 K could be achieved permanently by deep trough burial and sunless exposure to the sky.

Moonsoil has a low bulk density 1.5 – 1.6 gm cm^3 but the individual grain density is 3.1 – 3.5 gm cm^3. Thus half the volume of the surface layer is empty space and Moonsoil as such is a good heat insulator with properties akin to vermiculite. Optimistically, it may also be a good electrical insulator, and our proposed superconducting power grid may be no more than two parallel deep trenches laid side by side in sunless soil!

Table 2: Superconducting Ceramic.

Special Formula (1-2-3) RE $Ba_2Cu_3O_7$-x where RE is Rare Earth and 'x' is variable O to 2	
Yt $Ba_2Cu_3O_7$-x	Superconducting at 77 K
La $Ba_2Cu_3O_7$-x	Superconducting at 100K
Eu $BA_2Cu_3O_7$-x	Superconductive at 230K (Provisional results only)

Yt = Yttrium; La = Lanthanum; Eu = Europium: Rare Earth metals so far successfully utilised.

Superconductors from Lunar Rocks

Lunar rocks, as determined from analyses of samples obtained from Apollo and Soviet Luna missions [6], consist of: Basalt, Olivine, Pyroxene, Plagioclase, Feldspar and Ilmenite.

This yields the following in quantity: Oxygen (50 per cent by weight); Silicon, Aluminium, Titanium, Magnesium, Chromium, Vanadium and Iron (49 per cent by weight); and Nickel, Sodium, Potassium, Rubidium, Barium and Strontium (less abundant than on Earth and forming less than one per cent of the total); and Ytterbium, Europium, Yttrium, etc. (rare Earth metals in measurable quantities of several parts per million [7]).

In the event of there being no economical native sources of rare Earth elements in lunar rocks, it would be a simple matter to transport the very small quantities needed from Earth. This would probably be done anyway in the initial stages of setting up a superconducting ceramic facility.

Further Applications

Superconducting materials are also applicable to other areas. They will not "accept" magnetic fields and a piece of superconducting material will "float" above a permanent magnet indefinitely – the "Meissner" effect named after its original discoverer. A variant of this effect is able to detect minute changes in magnetic fields external to the system. Such highly sensitive detectors are known as SQUIDS (Superconducting Quantum Interferometric Detectors).

A supersensitive SQUID on Earth cannot be properly used to full advantage because the magnetic field of Earth is too "noisy". It is *not* in the steady state beloved of text books and shown by a compass, but is riddled with the quirks and whirls of the Earth's core and outer rock movements (quakes). Even the waves of the oceans can cause disturbances to a supersensitive wideband SQUID and drown out other signals.

Set up on the Moon where there is no dynamic metal core, where there are no oceans and where quake activity is several millions of times down compared with Earth, we might be able to detect the traces of other magnetic disturbances from other objects in the Universe. We might "hear" the pulsing of as yet unknown pulsars, the explosions of distant supernovae – and may be the magnetic field signals of a CETI system operating outside the conventional radio spectrum!

Electromagnetic Launchers

A major feature of recovering Moon minerals and metals has been the proposed use of electromagnetic launchers to place these materials either into the L_5 Lagrange position or other suitable orbital positions. This technique was a fundamental requirement of O'Niell's L_5 Colony proposals.

We now know that (when properly prepared) these latest superconducting materials can stand up to intense magnetic fields – but if suitable lunar rock superconductors are discovered – then an electromagnetic launcher could be set up very cheaply.

It could be operated during lunar night-time, the electrical power being derived from solar cells on the Moon's sunlit side and supplied to the electro-launcher by the loss-less superconducting power grid. All the construction materials would be native, little or no materials need be brought from Earth.

Magnetic Levitation Railway

The principles of using magnetic forces for electromagnetic launchers can also be used for rail transport purposes [8,9].

Using the Meissner effect, a superconductor will not permit a magnetic field to pass through it. A strong repulsive force is produced which permits levitation of the superconducting element. If this is attached to a carrier, then that too is lifted together with its payload. An alternating component to the magnetic field could provide a means of propulsion.

Magnetic levitation by superconductors has been often demonstrated – it is a standard test for a superconductor. So far railway applications have only been paperwork studies, the problems associated with liquid hydrogen cooling have been too formidable for magnets wound from niobium tin wire.

Because of the Moon's reduced gravitational field, a lunar rail transport system could carry a heavier load for a given magnet system than would its Earth-based counterpart.

Adopting a completely integrated approach could give rise to a totally superconducting power distribution system, combined with a magnetic levitation rail transport system and electromagnetic launchers.

Other New Superconducting Ceramics

Four basic components are involved in these ceramics:

- A rare Earth metal.
- An alkaline Earth metal.
- A cuprous metal.
- An oxydiser.

Examination of the Periodic Table shows that there are 17 candidate rare Earth metals, 10 alkaline Earth metals, four or five cuprous metals and four oxydisers. This suggests that at least 3400 compounds could be investigated in a hunt for new superconductors. In practice there would be many, many more, since some materials might be further mixtures of rare Earth metals, cuprous bases and oxides. There is room for a great deal of theoretical and practical work, the aim being to produce a particular type of crystal structure.

There appears to be no satisfactory explanation as to why these blends of ceramic should act as superconductors and the BCS theory (see box) developed for superconducting metals and alloys does not give the right predictions for these new materials. A new theory is needed.

Summary

The discovery of the new ceramic superconducting materials offers the following exciting prospects:

- A naturally cooled electricity power grid on the Moon to facilitate mining and recovery of minerals, and other heavy industries.
- A system of extremely powerful multiple electromagnetic launchers capable of transporting these materials to other parts of the Solar System, together with an integrated magnetic levitation railway.
- Superconducting SQUID detectors set up in super quiet surroundings permitting the detection of signals and data in a spectral band that was previously inaccessible (i.e. very very low frequency magnetic and electromagnetic fields). This could widen the vistas of astronomy and astrophysics, assisting in searches for magnetic monopoles – the elusive particles of high energy physics.
- SQUID detectors, which might also form the basis of a new type of SETI search system, would be impractical on Earth.

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History of Superconductivity

Superconductivity was first observed by the Dutch physicist Heike Kamerlingh Onnes, Professor of Physics at Leiden University. He was studying the behaviour of materials at very low temperatures and in 1911 found that solid mercury immersed in liquid helium at 4.2 K completely lost its electrical resistivity. Once a current had been started in a coil of such material it would carry on circulating for many days or even weeks.

Kamerlingh Onnes observed this property in many metals (see Table 1) and reported it in the proceedings of the University [1]. All of these materials lost their "superconductivity" (the name originally conceived by Onnes) at moderate intensities of magnetic field. No satisfactory working theory was forthcoming.

In the 1950's and 60's work on superconductive alloys resulted in the production of intensely powerful magnetic fields – far above those possible with ordinary ferrous metals such as iron or steel.

A workable theory was evolved by US physicists John Bardeen, Leon Cooper, and John Schrieffer (the BCS theory) which led to the award of a Nobel Prize in 1972.

Also during the 1970's Paul Grant of IBM studied the possibilities of room temperature superconducting plastics. This has resulted in the production of plastics with a conductivity similar to metals – but so far no superconductors.

Finally George Bednorz and Alex Muller of IBM Zurich announced earlier this year that they had discovered superconducting properties in a special series of ceramics cooled to liquid nitrogen temperatures.

By mid 1987 Paul Chu of Houston University Texas was announcing signs of superconductivity in a europium based ceramic cooled to only 230 K (-43°C). This is within the extremes of Antarctic winters on Earth.

Further work by Massachusetts Institute of Technology has used bonded gold as a matrix support for the crystalline ceramic structure. This allows the superconducting material to be rolled and drawn into tape and wire which may be twisted into very heavy duty cables.

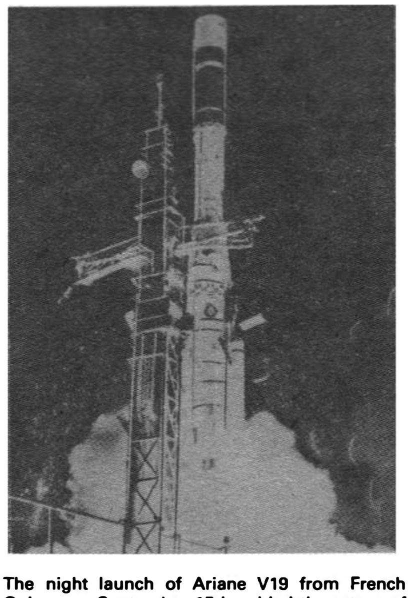
Thus, all of the items mentioned in the accompanying review paper have been researched and could be developed to form a practical proposition for industrial exploitation of the lunar surface.

Ariane Success Brings Relief to Commercial Operations

The long-awaited resumption of Ariane launches was heralded by the successful launch of Ariane V19 from Kourou, French Guiana on September 15, 1987. The injection of two telecommunications satellites, ECS-4 and Aussat K3, into near-perfect geostationary orbits was joyous news for the many commercial satellite operators in the Western world who are users of this launch vehicle. Prior to this launch, the Arianespace order book stood at a total of 46 commercial satellites to be launched, corresponding to a turnover of US$2.45 billion.

At the heart of Ariane's third-stage guidance and control system is Ferranti's IMS (Inertial Measuring System), which worked perfectly to place both satellites in orbit with an accuracy of 0.005 per cent error in apogee (amounting to 2 km in a total distance of 36,058 km) and zero error in inclination at 7 degrees to the equator.

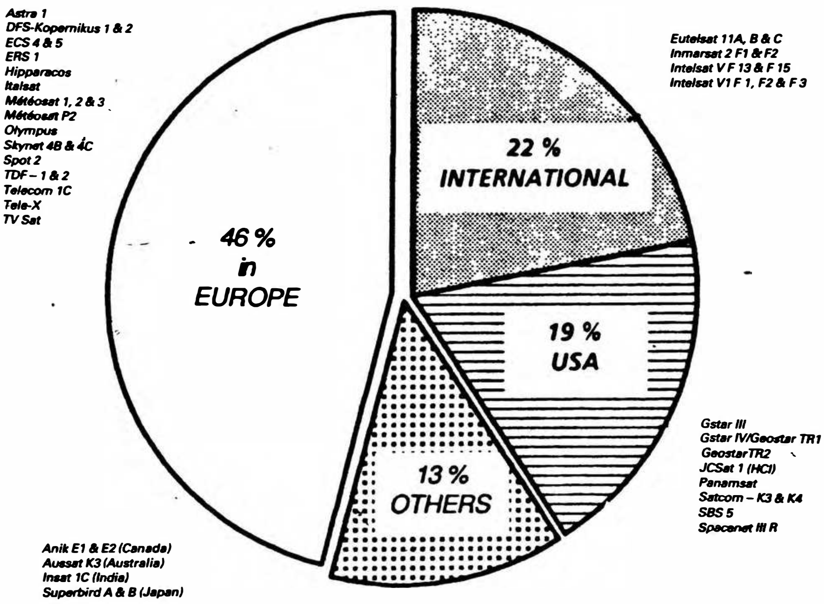
ECS-4, built for the European Space Agency by a consortium of 36 European aerospace companies led by the Space and Communications Division of British Aerospace, will be operated in orbit by Eutelsat (the European Telecommunications Satellite Organistion), with the designation Eutelsat 1 F-4.



The night launch of Ariane V19 from French Guiana on September 15 heralded the return of the European rocket to commercial operations. See also p.282. *Arianespace*

The satellite's 14 transponders, which operate at 14/11 GHz, will be used mainly for TV programme distribution. ECS-5 is to be launched in 1988. The nominal lifetime of ECS satellites is seven years.

Chart showing breakdown of Arianespace orderbook.



Aussat 3 is the final member a first generation satellite system comprising of three Hughes Aircraft Company HS 376 spin-stabilised satellites. The first two satellites were launched by the US space shuttle in August and November 1985 respectively. Aussat 3 carries two additional feed horns which provide coverage over the South West Pacific Region, including New Zealand.

The single largest application of Aussat satellites is the provision of broadcasting services for television and radio directly into homes in remote outback regions of Australia. It is known as the Homestead and Community Broadcasting Satellite Service (HACBSS) and is being provided, initially, by the Australian Broadcasting Corporation (ABC).

The service operates by using high powered (30 Watt) transponders switched into the spot beams. This enables high quality TV pictures to be received on relatively small, receive only, Earth stations ranging in size from 1.2 to 1.8 m in diameter and retailing at an average cost of A$2,500, including the costs of B-MAC decoding equipment. An important feature of the service is the use of B-MAC (Multiplexed Analog Component Type B) as the transmission standard. This is the first time that B-MAC has been used commercially in the world for an extensive application and the six channel chip used in the decoding equipment was commercially developed in Australia specifically for the service.

The HACBSS service provided by the ABC comprises television programming, two AM radio services and a stereo FM radio service. A teletext programme and information service is also avaliable. The establishment of HACBSS on January 26, 1986 brought televison and radio, for the first time, to an estimated 650,000 Australians living in remote areas of the country, who prior to the advent of Aussat had either received no radio or television services or at best were underserved. With the launch and commissioning of Aussat 3, the service provided by the ABC will be fully supplemented by a similar commercial service known as the Remote Commercial Television Service. Currently one RCTS service is in operation in Western Australia.

Communications On the Move

by Theo Pirard

In the next few years, the use of communications satellites to establish links with mobiles will be a major growth area and develop into a new and successful business activity.

Three factors are affecting the situation:

The first is the Mobile WARC (World Administrative Radio Conference) in Geneva during September which discussed the allocations of frequencies for the Mobile Satellite Service throughout the world: later this year, another WARC will determine the frequencies (L-band) for the Radio Determination Satellite Service.

Secondly, while communications satellites, even for long-distance and heavy traffic links, face strong competition from optical fibers – especially at this time of replacing old satellites and of problems with the availability of launch systems – they will always offer high flexibility and new opportunities for mobile communications.

Thirdly, development of microelectronics for small terminals from which to establish links by satellites is favouring a new market namely that of operators of aircraft, ships, trucks etc. In the 1990's it appears that ground systems for mobile communications by space will see a business boom.

Maritime Communications

The Inmarsat organisation, established in London on February 1, 1982, is operating a global system of satellites to provide telephone, telex, data, and facsimile, as well as distress and safety communications services to shipping and offshore companies. This 48-national cooperative has in service three COMSAT Marisat spacecraft (over the Atlantic, Pacific and Indian Oceans), the Marecs of ESA (Marecs A over the Pacific and Marecs B2 over the Atlantic) and four MCS packages on Intelsat V spacecraft. About 5,500 ship terminals are currently registered to use the Inmarsat services.

The Inmarsat II series of spacecraft, the first of which is due to be launched by Ariane in mid-89, will offer 125 simultaneous voice/data transmissions in L-band (satellite-ship-satellite) and in C-band (satellite-Earth station-satellite). It is designed to establish links with small terminals, such as the Standard C terminal at a ship Earth station.

The Soviet Union, which is a member of Inmarsat for 3.66 percent (its initial share having been 13.8 percent), is developing its own system for maritime communications. In operation is the Volna (Wave) satellite system for maritime and aeronautical services: it employs communications payloads installed on Gorizont and Raduga Statsionar spacecraft and functioning at UHF and L-band frequencies . For the 1990's, the USSR is developing the Morya satellite system (Morya means seaman) which is compatible with the Inmarsat system and uses L-band and C-band frequencies; Morya communications packages are already on existing Statsionar satellites.

Aerial 7 at British Telecom International's Goonhilly Downs Earth Station in south-west England. Built in 1983, it is currently being used for trials to provide a telephone service to aircraft.
BTI

Aeronautical services

Three Inmarsat member states have already announced plans to have aeronautical ground stations in operational service during 1988: Norway (representing the Scandinavian countries), Singapore and the United Kingdom. Later this year, British Airways and Japan Air Lines will be ready to offer pre-operational passenger telephone services onboard Boeing 747 aircraft. Two aircraft manufacturers, Boeing and Airbus Industries have already announced that they will design and manufacture airframes accommodating airborne terminals for satellite communications. Inmarsat is working with AEEC (Airlines Electronic Engineering Committee) in the development of an industrial standard which is intended to permit the aviation industry to begin data and voice services as quickly as possible, using existing Inmarsat satellites and also future generations of satellites that are either under construction or are planned. At this time, three manufacturers of communications equipment, each with its own technical approach, are proposing airborne systems for satellite links:

- Racal Antennas Ltd (Southampton, UK) is developing a blade-type flat antenna, which is an electronically steered, phase array; the Racal design brings together five independent phased arrays, which are switched into

Paging Via Satellite

An international paging service via satellite is to receive its debut shortly with a UK project to extend a domestic paging service through Inmarsat's spare Atlantic Ocean satellite.

The system is being launched by British Telecom using its coast Earth station at Goonhilly to provide a service to any craft or vehicle capable of carrying a suitable receiver unit.

The system will make use of standard BT radiopagers, which allow short messages of up to 90 characters to be sent with a bleep tone. The pager will be plugged into a purpose-built receiver connected to a flat plate antenna about 10 mm square. A printer will also be available as part of the package to provide written copy of messages. The whole unit is expected to cost about US$1,000.

Long distance trucks are likely initial users and airlines are also be expected to look at use of the facility, possibly as a means of getting an airline passenger to make a call via satellite communications (the service will initially be available air-to-ground only for passengers). On trucks, it is planned that the aerial could be mounted on the roof of the cab, with the printer and pager on the dashboard.

The service is designed to use off-the-self components and products should be on the market by the end of the year. By then modifications to the Earth station should be complete and the programme is expected to become fully operational at the beginning of 1988 with an experimental phase scheduled to last for six months.

ASN

operation depending on the zone of coverage required. This antenna will enter service in 1988 as part of the passenger telephone service which Racal, British Telecom International and British Airways plan to offer aboard transatlantic Boeing 747s.

- Ball Aerospace Systems (Boulder, Colorado) has already tested an electronically steered, phase array technology consisting of two conformal patches mounted on opposite sides of the fuselage; the antenna system is completed by a beam-steering computer, which activates the appropriate array and sends commands to the phase shifters to point beams in the desired direction. A simpler, single-element version of the Ball antenna was successfully tested in 1985. Ball plans to install its first high-gain arrays on a commercial airliner by the end of this year.
- E-Systems Inc. (Greenville, Texas) is proposing a SES-type (Ship Earth Station) antenna, consisting of a single helical element mounted on a platform 25 cm in diameter and protected under an aerodynimically designed dome of less than 40 cm in height. It is developing three models of an air-satcom terminal: the E-SAT 100 version, the largest, which is developed from the Inmarsat Standard A maritime terminal, is used on an experimental basis by two Boeing 747's. The E-SAT200 version is more compact and represents an intermediate step towards the production model, called E-SAT300.

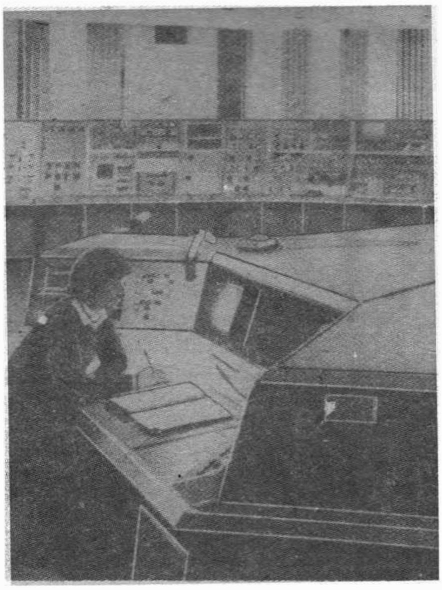
With the Inmarsat II spacecraft at least 125 aeronautical voice channels will be offered by each satellite. Inmarsat is evaluating the deployment of additional Inmarsat II satellites (designated Inmarsat IIA) in a modified version, incorporating specific spot beams for aeronautical services.

It is interesting to note the European role in the development of aeronautical links by satellites through the ESA Prosat/Prodat experiments. Inmarsat is providing free use of its space segment – the Marecs B2 satellite – to the SITA (Societe Internationale de Telecommunications Aeronautiques) for tests and demonstrations of an aeronautical data link employing 10 Prodat terminals provided by ESA; these terminals will be installed on aircraft belonging to SITA member airlines and the programme is schedule to begin in late 1987 or early 1988.

Cooperating with Inmarsat for initial tests, the US firm Aeronautical Radio Inc., (ARINC) is proposing for approval by the US Federal Communications Commission (FCC) its own global satellite commmunications system for aeronautical services. ARINC is a major supplier of aviation communications throughout the US and neighbouring ocean regions. It plans to enhance its ACARS (Arinc Communications, Addressing and Reporting System) service which has been successfully operational in the USA since 1978. For the tenth anniversary of ACARS, it hopes to extend services by means of an existing satellite system; this enhanced ACARS is to lead to the global AVSAT system.

The AVSAT project looks very ambitious; it has to be approved by the FCC and to get financial support. This six-satellite system, which is intended to provide redundant global coverage between 80 degrees N and S latitudes and a ground segment consisting of four regional Earth stations around the globe would cost $1.1 billion for its development. The AVSAT system is scheduled by ARINC to be fully operational in the mid-1990's.

The USSR and Japan are also developing space systems for aeronautical links. The Soviet Volna system with communications packages placed aboard Gorizont and Raduga Statsionar spacecraft offers L-band aeronautical services. The Japanese ETS-V, the first three-axis stabilised communications satellite of Japan, carries a technological payload to experiment with mobile satellite links for the control of aircraft over the Pacific, for communication, navigational aid, search and rescue of ships.



Inside the Ground Earth Station operational control room

ETS-V was launched on the recent three stage H-1 vehicle of NASDA in August (see p. 382). Australia also has plans to establish aeronautical links with the Aussat spacecraft.

Land-Mobile Links

Inmarsat has conducted successful trials on establishing links with mobiles – with a medical jeep in Swaziland and with a convoy of trucks in North Africa. ESA used the Marecs B2 satellite to test land mobile terminals within the Prosat experiments which are continuing with the Prodat stations developed for ESA by European industry. The Italian FIAR, German DORNIER and French SNEC are contributing to the manufacture of mobile terminals to be installed on trucks. In France, the Urba 2000 company is sponsoring an experiment with six trucks of the TAF frigorific transportation firm to use Marecs B2 for mobile communications throughout Europe; this experiment will last for one year with the technical assistance of SNEC.

ESA is studying the ARAMIS payload to test on a large-scale land-mobile system of communications by satellites. The ARAMIS payload will be part of the PSDE (Payload and Spacecraft Development and Experimentation) programme. It could be incorporated aboard the Olympus 2 payload to be launched by Ariane in the early 1990's.

Canadian Telesat, NASA and some 12 private US companies are looking for the establishment of mobile communications satellite systems for the 1990's. There has been serious disagreement between the USA and Canada over the development of the M-Sat project which concerns frequency allocations at UHF and L-band frequencies.

Contest for US Domestic Mobile Satcoms

An extraordinary scramble for participation in a US domestic communications mobile satellite system (MSS) is underway.

The requirement to form a single consortium set by the US Federal Communications Commission (FCC) has resulted in eight companies, including Hughes Aircraft Co, forming themselves into a single consortium with two others forming a second, leaving a third on its own.

The main aim of the US system is likely to be land-based use but aeronautical services will also be a possibility for the winning licensee. For this reason, the FCC is keen to open up the allocated aeronautical and maritime mobile frequency bands to all types of mobile communications users.

It faces an opposing view by European and other nations keen to maintain current frequency allocations in order to safeguard public correspondence and safety communications requirements of the aeronautical and maritime communities. *ASN*

First Aviation Ground Station

at Goonhilly, UK. *BTI*

British Telecom International is set to open the first Ground Earth Station (GES) to become operational within the Inmarsat aeronautical satcom system.

In August, BTI awarded a contract for the main computers for its new Earth station at Goonhilly Downs in the south-west of England. Worth about US$4 million, it was awarded to the Norwegian firm Electrisk Bureau (EB) and covers both hardware and software for the Access Control and Switching Equipment (ACSE), the nerve centre of any Inmarsat station.

Goonhilly is where the company's Inmarsat maritime terminal and most of its Intelsat stations are located. It is intended to provide a fully automatic service in the Atlantic Ocean region, offering up to 100 channels simultaneously, and is expected to enter service around May 1989.

An interim station has already been installed for use in a trials programme with British Airways (BA) and UK electronics firm Racal Decca, which is supplying the aircraft equipment.

BA plans to use it commercially once the demonstration period is over but, lacking any switching equipment, the initial station does not meet Inmarsat specifications. It will, however, provide a limited, operator-controlled service until the full-specification equipment comes into service. *ASN*

By deciding to use only the L-band spectrum for MSS purposes (Mobile Satellite Service) and by allocating the UHF spectrum to terrestrial public safety and cellular applications, the FCC was compromising the US-Canadian cooperation.

The Department of Communications of Canada is nevertheless going ahead with its M-Sat programme, presented as Canada's first mobile satellite communications system to provide remote areas in the Northern Territories with direct satellite links to portable terminals on land vehicles. Recently, the government of Canada made an appeal for private funding from industrial and financial investors. M-Sat is scheduled to begin providing service by late 1992.

Radiodetermination–Navigation Support

The Radiodetermination Satellite Service or RDSS which also uses L-band frequencies – just like the MSS networks – will provide users not only with precise location but also with short and quick digital messages. This message exchange capability – 100 to 150 alphanumeric characters per message – with mobile vehicles will enable links to be established on a global scale with ships, aricraft, trucks, and – why not? – pedestrians!

In the USA, four applications for RDSS networks were approved in August 1986 by the FCC: these were from Geostar Corporation, Mobile Communications Corporation of America, McCaw Communications and Omninet Corporation.

Of the four applicants, only the Geostar system is taking form with satellite packages and with the development of its own space segment (in cooperation with RCA/GE Astro Space). Geostar Corporation is at a very advanced stage of establishing a worldwide RDSS network with agreements signed with the French CNES (for the LOCSTAR network), with the Indian Space Research Organisation (ISRO), and contacts with China, Australia and Japan. In Europe, then in the Middle East and in Africa, the RDSS will be offered by the French LOCSTAR Corporation.

New Air-Satcom Terminal Ordered

The US company E-systems has received an order for its new digital Aircraft Earth Station (AES) for installation on a Boeing 747-200ST. The installation will be the first full-system AES designed to meet Inmarsat specifications.

Designated E-Sat-200A, the terminal will be installed alongside an E-Sat-200 analogue avionics unit, which had been ordered previously. The two will operate as parallel terminals through a single, eight-element, mechanically steered antenna of some 59 cm in diameter.

The E-Sat-200A is part of the complex evolution of E-systems aircraft Earth stations, which began with a modified ship Earth station called the E-Sat-100, the first of which went into service in 1986. A second started operation in June this year.

The digital unit will provide the basis for a production terminal, for which another, still smaller antenna is to be provided. The end result will be designated E-Sat-300 and it is scheduled for availability in 1989. *ASN*

Egyptian Earth Station

A new coast Earth station, located at Maadi, Egypt, began operation with the Inmarsat system in October. The Maadi station, owned and operated by the Egyptian National Telecommunications Organisation (ARENTO), is the twentieth coast Earth station – the first on the African continent – providing maritime communications services via Inmarsat.

Located on the outskirts of Cairo, it was officially opened by the Prime Minister of Egypt, Mr Atta Sedky.

US/Euro Firms Join Forces

GE Astro-Space Division (USA), Aerospatiale (France), and MBB (Germany) recently signed an agreement to jointly pursue international satellite opportunities. Foremost among such up-coming programmes are the impending Intelsat VII and Aussat II (Australia) communications system, for which Astro-Space Division will assume the role of prime contractor and provide the communications payload which will be integrated into a Spacebus 300 spacecraft, a three-axis platform developed by MBB and Aerospatiale.

Astro-Space Division (the result of a recent re-grouping of RCA-Astro and GE-Space Division) is active in developing and operating extensive satellite-based communications systems. These capabilities provide Astro with skills and experience directly applicable to the expanded services envisioned in the international marketplace.

UK Needs Euro-Space Business

ESA Plans For 1990s Yet To Gel

The ESA ministerial-level summit this month (November) faces the proverbial problem of 'squeezing a quart into a pint pot'. The 'quart' embraces major programmes such as the Hermes spacecraft, the Ariane 5 launcher, elements of the Columbus space station and a future spaceplane. The development of such projects over the next decade is now up for ratification. The 'pint pot' is ESA's present £1 billion annual budget, which needs to double over the next ten years to accommodate the quart-sized plans.

Recent estimates by CNES, the French national space agency, cost the 10-year development of Hermes at £3 billion leading to two to three operational flights in 1999 by which time a future spaceplane development could be well advanced. Voices in Europe, notably in West Germany (supporting Sanger-Horus) and the UK (supporting Hotol), would limit Hermes to a technology research programme into such areas as new materials, advanced avionics, complex software, life support systems and manned reliability requirements, which would then be available for the development of a more ambitious spaceplane with a really economic future.

Another area of doubt concerns the Columbus module for the space station and the conditions of NASA's acceptance of it due to pressure from the Department of Defence for the US to retain total control over space station operations. Although the situation is unlikely to be resolved by the November meeting, ESA is putting on a brave face, determined in the long run to realise its aim of space autonomy for Europe.

The present freeze on increased UK space funding has been dismissed by ESA as inconsequential to its future plans, which have recently received a welcome boost from the successful launch of Ariane V19. Speaking at the Kourou Space Centre, French Guiana, after the launch, Dr Reimar Lust, Director-General of ESA intimated, according to press reports, that Britain was not needed any more on its present terms of membership. However, much has yet to crystallize on the European space scene before a firm plan emerges for Europe's space infrastructure in year 2000.

UK Space Future In Doubt

The UK freeze on increased space spending has been defended by the Government on the grounds that the £4.5 billion limit on R & D spending cannot be breached in any circumstances. The restriction will therefore remain until a decision is taken on the switching of funds within the grand total, but just when this will come about, if at all, is clouded with uncertainty. The timing of the declared freeze was singularly unfortunate as it coincided with expectations of a positive Government response to the UK Space Plan formulated by the BNSC and calling for a trebling of the annual rate of space expenditure over the next five years. The main avenue left open by which confidence may be restored to UK long-term space involvement is now via the recently-formed body ACOST (Advisory Council on Science and Technology) which had this topic on its agenda at its October meetings. The prospects that either the October ACOST or November ESA meetings will crystallize the 1990s plans for either the UK or ESA must however be considered slender.

UK space industry, in the meantime, has been faced with the nail-biting frustration of a Catch '22 situation. Under ESA's strict industrial returns rule, member states receive contracts in proportion to their contribution to the ESA budget. Britain therefore stands to be squeezed out of major ESA projects as a leading force, unless the UK contribution to ESA is adequately increased. As a last-ditch move, UK space companies have started to mount a new 'private sector' space effort on a national front. By way of stop-gap action, certain key national space programmes are continuing at company expense. For the longer-term, the UK Industrial Space Committee, which represents Britain's industrial space community, has set up a new company called Space Ventures Limited with the object of promoting opportunities for the UK arising from the exploitation of space. While these developments aim to project UK space activity into the international forum, the scale of Britain's international activity through ESA remains tied to the level of the governmental contribution. The present level may optimistically keep 'a place at the table with the hope of being taken notice of', but will not maintain the UK's commercial viability in areas of its present space expertise, when other countries are blessed with the funds necessary for operating in world markets.

Although it may not yet be too late for European business to come to the UK in the 1990s, the sands of time are fast running out. ACOST is warned and should by now have come up with positive proposals for giving UK space involvement the long-awaited boost that it needs.

Comment

UK Space Plan

"We shall continue our subscription to the European Space Agency but at present we are not able to find any more money"

Commons Statement by Margaret Thatcher, July 1987.

Government's Decision Deplored

Sir, Like other members of the British Interplanetary Society I was disgusted at the Government's rejection of the increase in Britain's space programme, as proposed by the British National Space Centre, leading to the resignation of Roy Gibson.

While he was in charge at BNSC, there was a prospect of Britain taking its rightful place in man's advance into space. This refusal of funds is a return to the '70s, when we withdrew from ELDO, in which we were a major participant. Now, when Hotol offers a chance of playing a major part in future space transportation, we have the same lack of interest of Government in space. I am glad the Society has deplored the Government's decision and hope it will initiate a campaign to reverse it.

F.R. SMITH
Ashford, Kent

Write to Your MP

Sir, The current status of funding for space research in the UK must be deplored. The Prime Minister's attitude is unforgiveably short-sighted and it is particularly regrettable that her decision not to increase the BNSC budget should be made (after an angonising wait) only a couple of months before the prestigious IAF Congress, which is being hosted in Britain this year.

I see that correspondence has already appeared highlighting the need for a significant improvement in spending for space (***Spaceflight***, September 1987, p.343). While I agree wholeheartedly with such sentiments, in a sense such correspondence is 'preaching to the converted'. Before writing this, I wrote to my MP, and I suggest other readers do the same, in the hope that the Government's sad decision will be reversed before Britain's already damaged credibility is lost altogether. It is only by applying direct pressure to the policymakers that we can be assured of getting adequate financial support.

RALPH LORENZ
Henley-in-Arden, UK

British Ingenuity on the Shelf

Sir, The decision of Mr. Roy Gibson to resign as Director-General of the embryonic British National Space Centre because of the parsimonious attitude of the British Government to the space endeavour stirs up memories of other missed opportunities. I refer to Mr. Tom Smith's Project Mustard of yesteryear and the decision to cancel the Blue Streak launcher.

Looking at the enthusiasm with which Britain's partners in Europe are forging ahead one is left with the feeling that British ingenuity will be left on the proverbial shelf as far as space endeavours are concerned and will find itself in a feeble position when space is truly opened up with the use of reusable spaceplanes, as envisioned in the German Sanger concept and the American Orient Express, early in the next century.

PETER McEVOY
County Laoís, Eire

Shortsightedness in Space Funding

Sir, I would like to add my opposition to the Government's decision not to increase the BNSC's budget. This kind of short sightedness in funding would have prevented any space industry if the USA had applied it in 1957. We would then have been without compact computers, communications satellites (and therefore cheap telephone and television links), accurate weather forecasting and even that old cliché the non-stick frying pan. Just as in 1957, the USSR is stepping up its capacity – this time with Energia – but Britain simultaneously decides to drop out of the race!

A. McNAB
Glasgow, Scotland

Independent Space Capability for Britain

Sir, It is with sadness and regret that I heard of the recent resignation of Mr. Roy Gibson as Director-General of the British National Space Centre. The setting up of the BNSC in 1985 by the British Government appeared to redress a situation which has been allowed to drift for 25 years. Governments of both complexions have ignored space and its potentialities, both civil and military to the overall detriment of British interests. This new dawn of British space activity is to be eclipsed barely before it got started. As Prince Charles has said: "Britain is in danger of becoming a fourth rate nation in the 21st Century."

The record of achievements, project cancellations and wasted billions since the Second World War makes one want to cry in frustration. It runs from Blue Streak (1960), TSR2 (1965) and Black Arrow (1971) to Nimrod (1986) and the BNSC resignation in 1987. High points included the 1971 British launch of a British satellite from a Commonwealth launch base; followed almost immediately by its cancellation.

The 1965-66 cancellation of an entire generation of RAF aircraft was symptomatic of the 1960s and 1970s ethos of "retreat from Empire" mentality that the UK could no longer afford to "go it alone" on major projects. Is this the pattern to be expected for the future from the UK Government? From TSR2 to Black Arrow to Nimrod to ... Columbus? And yet look at France and Germany. Does anybody think that the French Government will allow its ideas in space to languish on the vine for lack of suitable partners to fund programmes and share risks? The payoffs in the 1990s and even now from decisions made in the 1970s and 1980s will come back to France and Germany.

Looking at the current world space scene, several questions come to mind. Is Britain about to miss the boat into the 21st Century – by rejecting the chance to keep up with the world space community? Are Britons to fly in space, if at all, courtesy of other country's space programmes and as passengers on American, Soviet and other spacecraft? Is the prospect of the novel "2010" to be realised, where the first interplanetary manned spacecraft to reach Jupiter would be built and crewed by the Chinese, or another national group? Four hundred years ago Britain was little regarded, but spent most of the intervening centuries building up a commercial empire, only to lose or give away most of it in the last 75 years. If we are not to disappear entirely from the world political scene in the next 100 years then we must have an independent space capability, including our own launchers and launch bases, which – with the new Hotol concept – could become a viable proposition if a small proportion of the money spent on Trident or the Channel Tunnel were to be made available. All that is lacking is the vision and political will to see Britain earn its title of Great again.

GEOFF WILLIAMS
Essex, UK

CORRESPONDENCE

Superconductivity in Space

Sir, Since the autumn of last year there has been considerable excitement in the World of Cryogenics and Physics engendered by the breakthrough in achieving Superconductivity at 90-100 K. This has important ramifications for terrestrial and space applications but if, as some researchers believe, superconductivity can be achieved at higher temperatures (room temperature has been suggested) then the effect would be nothing short of dramatic.

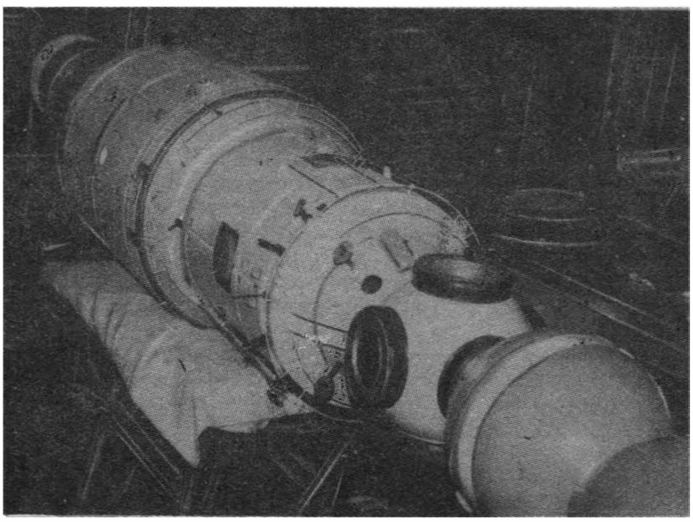
Until now, superconductivity has been achieved only at about 4 K to 23 K using Niobium and Titanium, Germanium or Tin element combinations. This new regime has been achieved using various combinations of the ceramic elements yttrium, barium, copper, oxygen and lanthanium which are alloyed by sintering. The resultant material is therefore brittle and lacks consistency or order and considerable efforts are now being made to produce materials with improved qualities and higher superconducting temperatures. Some experiments are being conducted using vapour deposition techniques.

If practical commercial materials are produced, the existing applications of superconductivity will be enhanced and some applications which have not been pursued because of technical difficulty or cost will become viable. Electronic devices and cable, which for all practical purposes have no electrical resistance, become smaller and lighter with less heat dissipation and higher packing densities and are therefore faster devices with greater current densities in power carriers. This affects computers, motors, generators, body scanners, magnetic separators, fusion power containment devices, magnetic levitation and power distribution.

As for ground-based electronics and electrics, the effect on spacecraft is to reduce power consumption and mass with the added bonus that 90-100 K can be achieved using passive radiation techniques (e.g. Meteosat radiometer) and the cryogenic systems of spacecraft such as IRAS and ISO can be used to advantage. The small stepper motors, which will be used to operate the wheels and gratings of the ISO IR camera, are good examples of useful applications. They operate in an environment below 10 K with very small power consumptions. Superconducting motors made by SEP under an STP contract are on trial but they use Niobium/Titanium or Niobium/Tin wire, superconducting at 4 K and 23 K. A motor superconducting at 100 K, would have a useful margin in the ISO application. Rotating joint motors such as Solar Array drive motors would also benefit from the technology.

A.W. SWALES
Bristol, England

The model of Mir with Progress and Soyuz TM spacecraft attached which Philipp van Stratum started to build shortly after the launch of Mir in February 1986.



The Road To Human Survival

Sir, Anybody actively or passively concerned with space research should have no doubt that it is the only road to human survival.

While we can see the overt signs of ecological decay and pollution – the destruction of the rain forests, the rising levels of carbon dioxide in the atmosphere and (possibly) the shrinking of the Van Allen belts, for instance – who knows what other changes are in progress whose symptoms will only become apparent when it is already too late to avert disaster?

I mean no criticism of Dr. M.H. Harrison's cogent and carefully reasoned article (***Spaceflight***, September 1987, p.325), which has its place in considering how space can best be commercially exploited. But the question is not whether manned space flight has a future, but whether the human species has a future. I submit that without extraterrestrial exploitation and colonisation, it has not. The Earth is slowly dying – we go up, or we go down.

ROGER W. WHITE
Lincolnshire, UK

Number of People in Orbit

Sir, I think Yaron Sheffer is one out in the calculations for the "Number of People in Orbit" (***Spaceflight***, September 1987, p. 344). In fact the figure for the two "rookies" on the Soyuz TM-3 mission, comes to 201 and 202. This figure has also been quoted in the press [1].

If Challenger had not met its disastrous end early on in the launch phase of the flight, its three rookie crew members would have shared the 200th person in orbit record. As it is, Alexander Laveikin, making his space debut on Soyuz TM-2, makes the record books as number 200.

I see Yaron also says that Soyuz TM-3 is the 114th space flight. I presume then, that the two manned sub-orbital missions of project Mercury and the Russian Soyuz 18A [2], which after all did get 90 miles up, are not counted.

MIKE KITCHENER
Hertfordshire, UK

References
1 Financial Times, August 1, 1987.
2. Manned Spaceflight Log, Tim Furniss, 1983.

Mir Complex 1/10-Scale Model

Sir, The Soviet pavilion at the 1987 Le Bourget Air and Space Show was most impressive – especially the Mir combination mock-up. But after a good look at it I came to the conclusion that it was a rebuilt version of the Salyut space station shown in Paris in 1985.

The Kvant was also different from the pictures I have of the Kvant trainer at star city.

French cosmonaut Jean Loup Chretien told me that in the near future four modules will dock around the multiple docking adapter. Now that is nothing new, but his first flight onboard Mir will take place after the four modules have been attached. This would mean that all four modules will become a part of Mir in 1988. Asking what these modules look like he told me that they are all Kvant shaped, but with a different interior with equipment for such things as biological and medical experiments.

For a year and a half now my interest in manned spaceflight has been in the Mir space station, because I am building this on a 1/10 scale.

PHILIPP van STRATUM
Asten, The Netherlands

CORRESPONDENCE

A Space Agency for the Far East

Sir, Articles in recent issues of ***Spaceflight*** [1,2,3] show the present capabilities and future aspirations of three major Far Eastern Countries. Other nations in the region are also increasingly realising the importance of space technology (Indonesia, with regard to Comsats, and Australia with its possible establishment of a future spaceport at Cape York). Added to this are a large number of rapidly industrialising nations in the Far East with their emphasis on new technology (Singapore, Malaysia, Thailand, South Korea, Tiawan, Philippines etc).

An ESA style grouping of all, or just some of these nations, would provide a fourth space community (after the USA, USSR and Europe) which, in years to come, could represent a sizable proportion of the world's population, industrial, commercial, and political activity.

Whether such an organisation will ever come into being depends on many factors, but ESA itself shows what can be achieved given the right conditions.

P.A. HEARD
Cumbria, UK

References
1. "Will Japan Steal the Thunder?", *Spaceflight*, November 1986, p 390.
2 "India: The Way Forward", *Spaceflight*, December 1986, p. 430
3. "China – In Business and Advancing Fast", *Spaceflight*, February 1987, p. 62

Space Stations Photographed

Sir, In a recent article in Soviet Scene (***Spaceflight***, June 1987, p. 238) concerning two photographs of the Mir and Salyut 7 space stations taken by BIS Fellow Alan Lawrie as they passed in close formation over Southern England on June 26, 1986, it was stated that it was believed that this was the first time such photographs had been published. Mr Lawrie and others may be interested to know that a colour photograph of Mir and Salyut 7 flying in formation as they passed over Washington, DC, USA in April 1986 has been published as part of a Soviet space programme feature [1]. The photograph was taken by Houston resident Mr Paul D. Maley, a regular monitor of Soviet spacecraft. The two spacecraft are shown on the same image and appear bright and clear. However the distance between them does appear to be considerably greater than shown in Mr Lawrie's photograph.

Such photographs again highlight the importance of amateur work in the field of space flight monitoring especially of those flights conducted from the Soviet Union.

KEVIN J. LOWDEN
The Scottish Council for Research in Education
Edinburgh

REFERENCE
1 National Geographic Magazine, October 1986, p 443.

Challenger Memory

Sir, While holidaying in Honolulu earlier this year, we visited the "Cemetery of the Pacific" in Punchbowl Crater, which contains the graves of thousands of American people who died in, or had close connections with, the Pacific area from the Second World War to the present day.

We were very moved to see the mass of fresh flowers which covered the grave of Ellison Onizuka, the Challenger astronaut who came from Hawaii. We were told by our guide that the flowers were renewed daily by the many Japanese visitors, fellow Zen-Buddhists of Ellison, who regard his grave as a holy shrine.

M.E. MASON (MRS)
Surrey, England

Spaceflight

Sir, Each edition of your magazine ***Spaceflight*** brings me a great deal of interesting and useful information which is almost always up-to-date. Even details about our own space programme, which I do not know and which I think many of our own people do not know either, I find in your marvellous magazine. Your magazine makes me feel that progress has not stopped, that humanity goes on ahead opening up new prospects and developing new technologies. Thank you for that. It helps me to endure living in this troublesome world.

I am an engineer, aged twenty-eight, and am very interested in linguistics as a hobby.

ANDREW V. VYGONSKY
Kiev, USSR

Spaceflight

Sir, I recently read the August 1987 issue of ***Spaceflight*** and was most impressed, particularly with your coverage of the Soviet scene in which I am particularly interested. As detailed information of the Soviet space programme is not readily available, I see your publication as an excellent source of authoritative and up-to-date comment thereof.

R.C. SINCLAIR
Roleystone, Western Australia

Mir's Docking Ports

Sir, Over the past 18 months, we have all learned a great deal about the Mir Space Station, much more than any previous Salyut Station.

We saw pictures of its launch only 24 hours after the event on February 20, 1986 and within a month were given a guided tour from space by the Soyuz T15 crew. The best was yet to come. Two full-scale mockups have allowed analysts to gain much more detail than ever before.

On May 24, 1986, during a British Parliamentary visit to Moscow (***Spaceflight***, August 1986, p.291), Western journalists viewed the Star City mockup and more recently the world's aerospace community had a hands-on tour of a new mockup at the Paris Air Show (***Spaceflight***, August 1987, p.273). It is of interest to note that both mockups differ in one curious way, not just from one another, but also from the Mir station in orbit.

From cutaway diagrams and interior photos of Mir's revolutionary multi-docking unit, it is apparent that only two of its five ports retain conical receptacles (not including the rear service port) which will allow hard docking by approaching craft, while the remaining three ports can only allow soft docking via the Ljappa Arm System (***Spaceflight***, May 1987, p.184).

An interior photo of Mir's multi-docking unit shows the forward and upper ports to have the conical receptacle, while the Star City mockup shows the forward and port docking ports to have receptacles. And, finally, the Paris Air Show mockup shows the forward and starboard docking port to have receptacles. In each case the remaining three ports have no such receptacle.

What's going on? Are the Soviets trying to confuse us? Or are they rotating the multi-docking unit 90 degrees on both mockups in order to display the second receptacle? I believe this to be the case.

Why the need for an extra receptacle? It seems quite clear - either for a third Soyuz TM to allow a total of nine crew simultaneously, or for a second Soyuz TM, thus leaving the rear port permanently free for a new advanced Progress vessel, due this year or next.

The use of these ports will certainly be an exciting area of future study. Can anyone add to this?

LEE CALDWELL
Toronto, Canada

CORRESPONDENCE

SL-16 Launcher Variants and the 'Small' Soviet Shuttle

Sir, The Russian Heavy Lift Launch Vehicle 'Energia' is obviously attracting much attention at this moment in time. What is more intriguing to me, however, concerns its SL-16 type boosters and their alternative use as a Medium Lift Launch vehicle with possible variants.

It would appear from press coverage of the launch of Energia that the Medium Lift Launch Vehicle has a single engine producing 450 to 500 tonnes of thrust and dimensions of some 5 metres diameter by 40 metres length and is recoverable after use. If the above statement is approximately correct, I would suggest the following possible variants:

1. A single core recoverable stage plus a second stage (not recoverable) to launch around seven tonnes. This would be an SL-4 (A2) replacement (and a general workhorse for the Vostok/Soyuz series).
2. Single core stage and two equal boosters (all recoverable) with a second and possible third stage to launch 20-25 tonnes. This would be a replacement for the Proton SL-12, SL-13 (D1) series.
3. Single core stage plus four equal boosters (all recoverable). The core stage ignites at altitude and with a second stage can place a 35-40 tonne small shuttle (or spaceplane) into LEO. With third and fourth stages it will send a 9 tonne payload to the planets. (This is an extra launch capability whose performance lies between that of the Proton and the Energia).

I illustrate the modular standardised assemblies which seem to me to be a logical progression from old to new designs that offer greater flexibility and efficiency with considerable cost improvement. I mention 'small' shuttle but the Russians may use another name, reserving shuttle for the big vehicle to be used in conjunction with their large space base. Statements made by the Russians, Western press and individuals do not make sense unless one assumes two types of vehicle.

A suggested specification for the 'small' shuttle is:

Crew and passsengers	10
Payload	5 tonnes
Total Weight	40 tonnes
Total number envisaged (2/3 for military, 1/3 for space station use)	20 – 30
Operation	Manned or unmanned

The cargo bay 5 m long by 3 m diameter is designed to accept near standard modules for minimum integration time, which is important for military use. For space station use, the cargo bay would transport stores and/or crew members and may also be equipped as a small space laboratory. The docking system, which is compatible with the current Soyuz, is at the rear of the vehicle and would be removed for non-station use.

Comments from anyone who might be following these developments would be greatly appreciated.

R. HARVEY
Portsmouth, UK

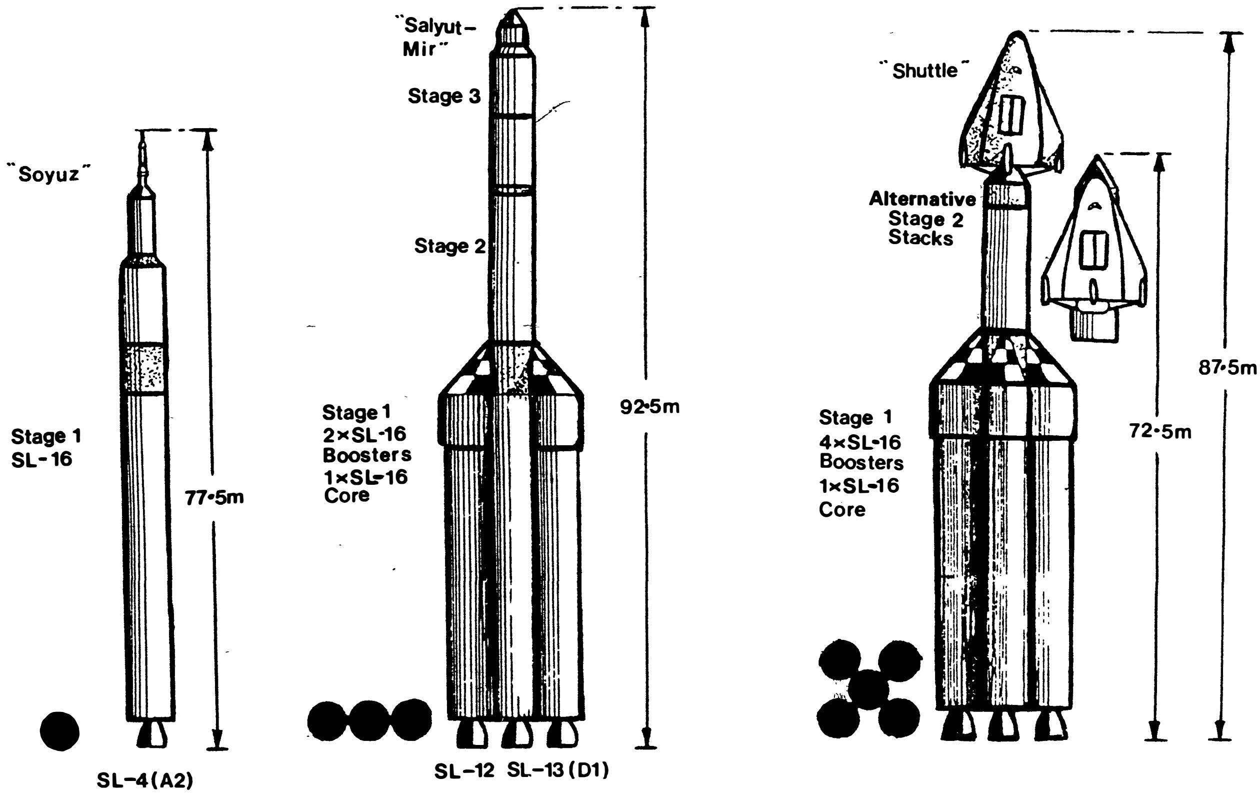
A response to Mr Harvey's letter has been provided by ***Anthony T. Lawton****, who writes:*

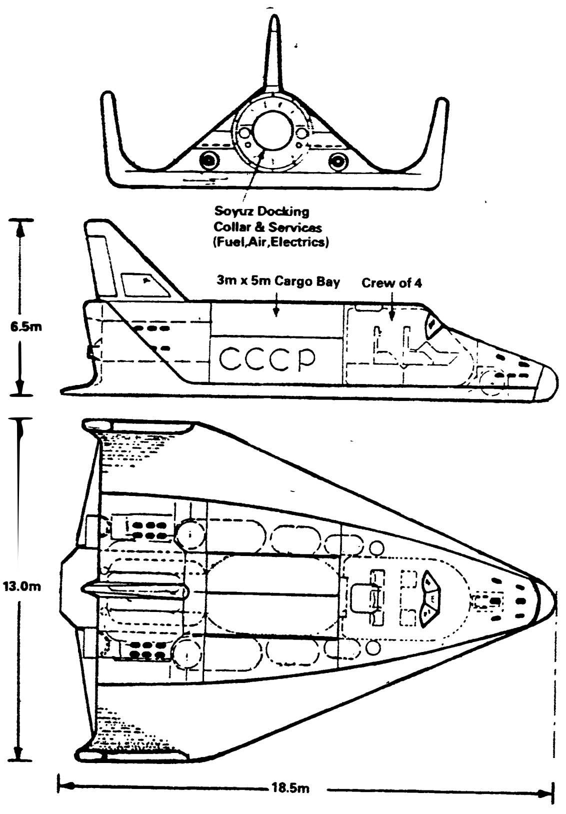
Most Western authorities would agree with Mr Harvey that there are two different types of spaceplane or shuttle being developed in the Soviet Union.

Earlier speculations had always assumed a small vehicle (often quoted as 'Kosmolyot') and the existence of the much larger Buran ('Snowstorm') which came as a surprise when first quoted by Western circles in 1982-83.

By July 1987 reports indicated that the smaller vehicle would be "tested shortly". It is my personal opinion that it has already been tested in short sub-orbital hops over selected sections of the Soviet test ranges. These have not been rated as space flight and are not to be found in 'Satellite Digest' or similar logs. 'Energia', the Heavy Lift Launch Vehi-

Possible SL-16 Variants.





Small Soviet shuttle: Payload 5 tonnes; All-up weight 40 tonnes; Launch vehicle 5 x SL-16.

cle, has of course been heavily publicised and will continue to be promoted, whereas the SL-16 Medium Lift Launch Vehicle has been launched (successfully) several times without comment.

Mr Harvey is also probably correct in his assumption that the Soviets are now persuing a more cost effective space programme. Soyuz and Proton and their derivatives will still be used but gradually phased out and the SL-16 and *its* derivatives phased in as general purpose workhorses. Mr Harvey's comments and sketches fit the known configurations used by the Soviets for the SL-16. The SL-16's are manufactured singly and in matched pairs – the latter being strapped together in the Energia assembly. The vehicle lends itself to Mr Harvey's conjectures in a typically Soviet fashion.

Following Mr Harvey's logic the Soviets would have the future capability of lifting payloads of seven tonnes to 300 tonnes to LEO with only two basic types of launch vehicle.

As regards the 'small' spaceplane itself, I personally think it will eventually be revealed as an accurately scaled up version of Kosmos 1445 which is too well engineered to be a mere "proof of principle" test vehicle. With regard to its size, my personal choice would look to a slightly smaller vehicle of 20-23 tonnes similar to the ESA Hermes. Perhaps it is not a coincidence that negotiations are attempting to standardise a Franco-Soviet docking arrangement. We may eventually see Hermes launched atop an SL-16 assembly.

Mikial Gorbachev's appearence has hastened the process of impressing cost effectiveness. Immediately prior to the launch of Energia he visited Tyuratam, accompanied by the leading officials of the Army, KGB and the Space Programme, and witnessed three satellite launches. He then made a major speech assuring workers they could be "proud of what they were doing". All technology used was Russian, not one item came from the West.

I suggest that he went to Tyuratam to see for himself that the huge sums of taxpayers money were being efficiently spent. He appears to have been satisfied – a fundamental necessity in view of the future proposed Soviet plans for the 'Development of Space'.

Energia: Possible Operating Modes

Sir, With reference to Mr Lawton's interesting article in ***Spaceflight*** (August 1987, p.285) on the Soviet booster Energia, I would like to offer some comments.

The August 1987 issue of *Pravda* in English states that Energia's total thrust is 4000 tons not 3000 tons as portrayed in the article. Each of the four strap-on boosters generates 800 tons thrust and each of the central four engines generates 200 tons thrust. *Pravda's* Energia weight is 2000 tons with a payload of 100 tons to LEO, the same as Mr Lawton's figures which are the same as the Pentagon's. This seems to be the super safe, manned, configuration of Energia. Half the engines could fail and you would still keep going. I would suggest that the 3000 ton version would use the same engine configuration with stretched tanks. The unmanned version of their shuttle could use the 3000 ton mode carrying, perhaps, 75 tons of cargo.

As far as bringing the engines back from orbit, I doubt they would use the shuttle to do it, simply because the engines would be too big and heavy for the cargo bay. I suspect that the Soviets want the return capability of the shuttle for more important things such as people, processed materials and scientific equipment. It is possible that they could use jet engines to increase their return weight, but the rocket engines would still be too bulky, displacing valuable cargo. Most likely they would use some sort of ballistic return mechanism, built into the engine compartment, to automatically send them back.

I was impressed by the high specific impulse values given for the engines. They would allow Energia to carry the engine return equipment and still put up heavy payloads. Since the Soviets have announced that they plan on developing solar power satellites as well as a materials processing industry in space, it certainly makes sense that they would make use of the external tanks, rather than having them burn up. Two simple uses could be for fuel storage or for construction materials.

Mr Lawton did not discuss the SLX-16 which I call 'Energia Junior'. This launcher appears to consist of one strap-on booster engine for the first stage and one central engine for the second stage. Stage weights should be around 400 tons for the first and 300 tons for the second. This gives a total of 700 tons with a first stage thrust of 800 tons and a payload of about 35 tons to LEO. These figures are different from the Pentagon's, but just looking at their diagram in *Soviet Military Power* one has to question how they ever got a total weight of 400 tons with a 15 ton payload to LEO. I originally thought the SLX-16 was even bigger because the first stage engines were supposed to be only 600 tons thrust – I thought they were using two of them, giving perhaps a 1000 ton launcher. The SLX-16 is probably a test vehicle for both engines of the Energia, as well as a powerful rocket in its own right.

GEOFFREY BESLITY
New York, USA

Energia

Sir, I would like to respond to two letters appearing in the ***Spaceflight*** issue of September 1987; C.M. Hempsell's "Energia Payload" and M.Q.Hassan's "Thoughts on Energia".

First I would point out that the major Soviet launch vehicles used for civilian activity have been named after their first significant payload. Thus, first the Vostok and then the Proton were both named after the spacecraft/satellites that they launched in 1961 and 1965 respectively. The upgraded Vostok then led to the Soyuz booster. That being the case I propose that Energia is named after the proof-of-concept (scaled down, of course) solar power station it carried on its first launch. Supporting that contention is the remark of Gury Marchuk of the USSR Academy of Sciences that Energia will be used to launch "experimental solar power plants". Solar

power plants convert solar energy to microwaves which are then beamed down for use on Earth. Mr Hempsell is I believe correct when he states that the payload was intended for geosynchronous orbit. It is far too early for full-scale solar power stations as his letter might imply. The Soviet space programme does not take such great leaps all at once. They are cautious and methodical. It will also be a long time before there are geosynchronous manned space stations. Before that there well might be manned stations in lunar orbit, however.

Mr Hassan's calculations on the thrust of Energia do not agree with the announcement that the total thrust of the vehicle at lift-off is 4000 metric tonnes; 800 tonnes for each of the kerosene/LOX straps-ons and 800 tonnes for the core LH2/LOX engines. It was also announced that the engines aboard were "the most powerful in the world". If interpreted as the sum of all the engines it is easily true as 4000 mt is 8.82 million lb, which is clearly greater than that of Saturn V (7.5 million lb). If each strap-on is a single engine then the strap-on single engine thrust is 1.73 million lb which exceeds the 1.5 million lb of the Rocketdyne F-1. The number of nozzles on Energia has yet to be clearly shown. Obviously, should each strap-on contain a single nozzle then the Soviet Union has produced the most powerful booster from either of the prior viewpoints.

One hopes that the era of Glasnost will lead the Soviet authorities to tell us more about their superb new launch vehicle. Clearly, a new vista in the exploraton of the Solar System is upon us as Energia comes to operational use.

SAUNDERS B. KRAMER
Maryland, USA

Energia: A 3-D Interpretation

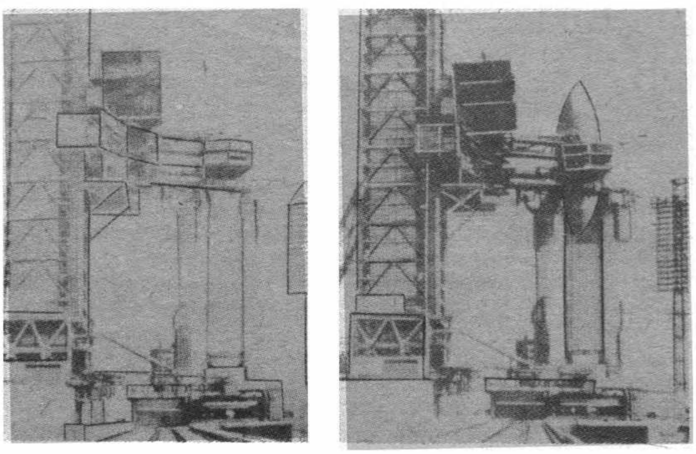
Sir, Further to Mr. Lawton's fascinating article on Energia in ***Spaceflight*** (August 1987, p.285), it is interesting to note that the picture published with it, while similar to others published elsewhere, is from a viewpoint slightly to the left.

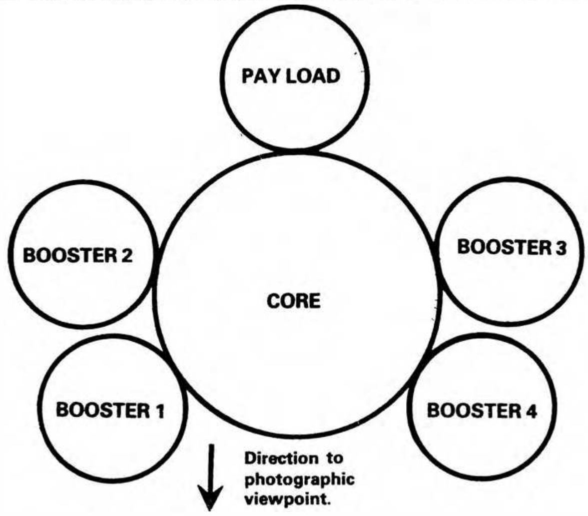
The possibility therefore arises of making a series of stereoscopic views, by reducing pictures to a common scale and correcting vertical distortions. I enclose one such example.

This leads to many additional observations. On the left of the rocket both sideboosters are visible while on the right the line of sight passing the nearer sidebooster apparently grazes the further one. The four sideboosters are not therefore diametrically opposite each other but are positioned as in the accompanying diagram.

This diagram also shows the payload. The sideboosters measure accurately at half the diameter of the core, as in Mr Lawton's diagram. Photographs published elsewhere indicate, as closely as it is practicable to measure, that the payload is the same diameter as the sideboosters.

Photographs of Energia taken from slightly different viewpoints and scaled to provide a stereoscopic pair.





Approximate plan of Energia core, boosters and payload, as photographed (Booster 2 visible behind B 1. B 3 and B 4 almost in line).

Given the overall height of the rocket as 60 m, the core diameter and sidebooster diameter respectively scale at 9 m and 4.5 m, as the average of measurements taken off perspective-corrected prints. One cannot assume that these rounded-off figures are exact but they should not be more than a few per cent in error. They seem to preclude the 8 m and 4 m given in Mr Lawton's diagram.

We pass from these dimensions to the volume and weight indicated for fuel. Given mildly pessimistic assumptions, the volume would appear adequate for the fully-fuelled rocket plus payload to lift off at over 3000 tons. One assumes that the official figure of over 2000 tons related to the rocket as prepared for launch on May 15.

Even without recourse to a six-sidebooster configuration the available stretch in Energia's capability would appear to be adequate for any conceivable astronautic or military requirement for many years. Flexibility seems to be the design keynote. Sideboosters and payloads can be attached variably, up to a total of eight. A six-sidebooster configuration, launching at over 4000 tons, could lift two payloads dimensionally similar to the May 15 payload but jointly weighing over 200 tons. The May 15 payload was dimensionally comparable to the four-module Mir complex.

Mr Lawton's conjecture regarding the engines seems entirely borne out by the long feature on Energia published in *Izvestia* on May 23, based on an interview with Academician V. Avduyevsckiy.

Reverting to the pictures, the perspective is such as to suggest that they were taken with a 35 mm camera using a 30 mm focal length lens. The stereoscopic prints may successfully fuse into a 3-D image for some people by looking at them with the naked eye, but lenses of about four to seven inches focal length will help matters and give larger magnification. The former gives a result approximating to the scene as apparent to the photographer, in terms of angular sizes.

We are looking at the 'back' of the rocket, i.e. we are diametrically opposite the payload. The direction of view is North East and the time about 1½ hours before local noon. The pictures were not taken simultaneously but only a short time apart. Evidence of activity shows up in features which do not exactly correspond.

The sidebooster configuration of the May 15 launch, in which the sideboosters are set back further from the payload than the latter's dimensions necessitate, seems to reflect the needs of a winged shuttle launch. This configuration appears to be reflected in the fixed layout of the launch area. In other words, this configuration may be the standard configuration for launches from this pad.

TONY DEVEREUX
Essex, UK

SOVIET SCENE

Endurance Record Broken

On September 30, 1987, Yuri Romanenko broke the space flight endurance record of 236 days 22 hours 50 mins held by Vladimir Solovyov and Oleg Atkov following their Soyuz T10 launch on February 8, 1984. The record is expected to be extended by a further two months by the time Romanenko returns to Earth. The record would also have been shared with his erstwhile companion cosmonaut Alexander Laveikin but for the latter's return to Earth for medical reasons and replacement by Alexander Alexandrov at the end of July. The months of May to August were an eventful time at Mir with many comings and goings and much on-board activity, reported here for *Spaceflight* by *Neville Kidger*.

Progress 30 in Flight

Between May 11 and 13, 1987 Soviet leader Mikial Gorbachev visited the Baikonur Cosmodrome on a secret visit where he saw the facilities for the launching of the huge new booster, Energia, and witnessed one or two launches of Soviet spacecraft.

In a keynote speech to workers at the Cosmodrome, Gorbachev praised the two cosmonauts on Mir – Yuri Romanenko and Alexander Laveikin – whom he said were "keeping their difficult vigil".

On May 15 TASS reported that the cosmonauts had been occupied in activation of the Kvant module and Earth observations. The agency said that Kvant was equipped with an "Electron" system which "is one of the elements of the system for maintaining the gaseous composition of the atmosphere inside the manned orbital complex and for obtaining oxygen through the electrolysis of water".

At 0402 GMT on May 19 Progress 30, another of the unmanned cargo spacecraft which are used to resupply the complex, left Baikonur and docked with the rear docking unit located on Kvant at 0553 GMT on May 21. The spacecraft delivered fuel for the engine of the complex, food, water, equipment, and mail for the two-man crew.

In late May the Soviets reported that the complex was experiencing a power supply shortage due to two things:

1. The orbit of the complex was at such an angle with relation to the Sun that there was much less sunlight available to power up the batteries of the complex to enable the full complement of experiments to be carried out.
2. The delay in erecting a third solar panel array outside the complex, which would have supplemented the power available and allowed the Kvant module to be fully powered up.

The EVA to erect the new solar panel had originally been scheduled for early May but was postponed after the cosmonauts were reportedly being overworked. Because the EVAs are tied to those portions of the orbit when the complex is under the most sunlight illumination in the northern hemisphere, the Soviets had to wait until the geometry of the orbit was again correct (one western analyst says that the specific conditions for EVAs arise every eight weeks). Until the EVAs could be conducted the two men and the ground controllers had to manage power usage carefully.

The work that the men were engaged in through early June involved tests of the control of the complex (in preparation for the Kvant observatory activation), unloading Progress 30, further Earth observations and routine medical checks.

> ***"EVAs are tied to those portions of the orbit when the complex is under the most sunlight illumination in the northern hemisphere."***

Kvant in Action

On the night of February 23/24, 1987 a supernova was observed in the southern sky in the Great Magellanic Cloud, one of two nearby galaxies which appear as dull cloud-like objects in the skies of the southern hemisphere. The supernova became an object visible to the naked eye and was the first such event to be seen by the naked eye since 1604 (***Spaceflight***, May 1987, p.202). The first observations of the event from space were conducted on February 24 by the geostationary International Ultraviolet Explorer spacecraft which had been launched in January 1978.

On June 9 the two Mir cosmonauts, under the control of the ground, became the first orbital astronomers to observe a supernova visible to the naked eye when the "Roentgen" observatory mounted on the outside of the Kvant module was directed to look at the object. Over the next several days the men were to be involved in many more observation sessions with the observatory. The targets included the site of a possible neutron star in the constellation of Cygnus.

EVA from Mir

The postponed EVAs to erect the solar power panel delivered on Kvant were conducted on June 12 and 16. The Soviets announced that the two men were completing preparations for the first EVA on June 12 and the actual event occurred that night.

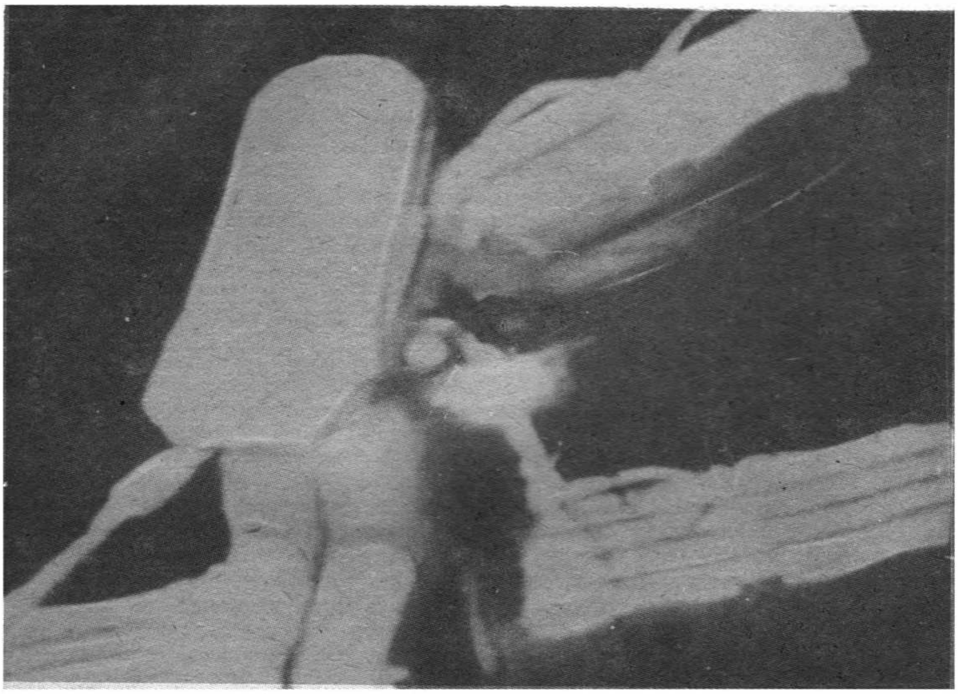
The EVA began at 1655 GMT. The cosmonauts had depressurised the Mir docking unit and the Orbital Module of the Soyuz TM-2 spacecraft in order to accommodate the bulk of the new panel (the Soviets have revealed that a larger, more spacious airlock will be delivered to Mir at a future date). The men then floated out into space with two "fairly bulky containers – one containing the solar battery panel and the other a unique device.... (containing) a fairly long lattice mast structure which pulls out the solar panel like a concertina," the Soviets said.

The first EVA was to install the container with the mast onto the area of Mir allocated and the central rod of the device was successfully inserted onto the correct position. TV pictures of the cosmonauts in space were later released. With the job done rather faster than anticipated the cosmonauts were instructed by Valeri Ryumin to go back into the space station. It was later revealed that Romanenko and Laveikin had conducted the first EVA without being attached to the station by means of tethers, at their own requests. It had lasted just one hour and 53 minutes.

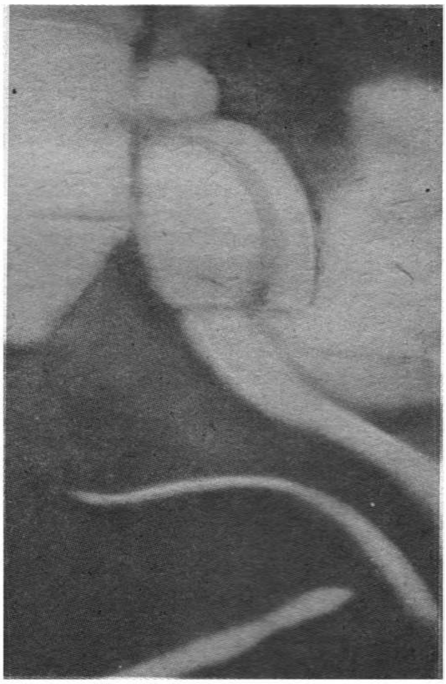
The second EVA would see the cosmonauts take out "the second floor of the structure, one more frame and two panels of photoelements," the Soviets revealed. The whole structure would then be unfurled and the electrical connections made to enable the new panel to begin providing power to the complex.

At 1530 GMT on June 16 Radio Moscow announced that the cosmonauts had "right now" begun the second EVA. The TV report which followed shortly after showed two space suited figures in the Zvodznyy Gorodok hydrotank performing operations with a mock-up of the solar panel.

The first job for Romanenko and Laveikin was to connect the panel to



Romanenko floats infront of the new solar panel erected during EVAs on June 12 and 16.



Mohammed Faris on Mir during a TV broadcast.

the electrical system of Mir. All the power cables had different colours as an aid to the task.

On July 2 the cosmonauts conducted a feasibilty study of the techniques for the clinical analysis of blood in space. Up to then blood samples were taken in space and examined back on Earth.

The cosmonauts also spent much time photographing and observing sites on Soviet territory as part of their programme for studying the natural resources of the USSR and monitoring the environment.

On July 7 the integrated propulsion system of Mir was refuelled from Progress 30. The cargo spacecraft was used the next day to adjust the groundtrack of the complex. On July 10 another adjustment was made by the cargo ship.

Reports over the next few days spoke of experiments with the "Fiton" biological installation in which plants were being cultivated, the Svetoblok unit in which a Gel experiment was being conducted, the Yantar and Kritallisator unit (which was made in Czechoslovakia) and electrophoresis processing activities.

During July 14 the Soviets said that the men had conducted observations of the USSR over the areas of the Far East, Moldavia, the Crimea, the Pamir Mountains, the Caspian Depression and other areas. The areas of the sky which the cosmonauts had been studying with Kvant's observatory included areas of the constellations of Cygnus, Centaurus and Hercules. The first UV pictures had also been taken somewhat earlier with the Glazar telescope.

The latter telescope has a 40 cm diameter main mirror and records its observations onto film which is enhanced by an electronic amplifier. The cosmonauts on Mir will return the rolls of film to Earth at intervals. The Soviets say that tens of thousands of pictures will be taken by the Glazar telescope during its lifetime.

On July 15 it was revealed that the men had been participating in another Earth Observation experiment involving countries allied to the Interkosmos organisation. Past editions of Mission Report in ***Spaceflight*** have documented these experiments which occur during the summer months. The 1987 experiment was called "Tele-Geo-87" and took place over the territory of Poland. As in the previous experiments the pictures taken by the orbiting cosmonauts would be supplemented by pictures from the Meteor satellites, aircraft and samples taken from the observed sites.

The cosmonauts were again ahead of their timeline and TV viewers could see the cosmonauts later working with the central rod and the solar panels.

The next job was to unfurl the panels themselves. The Soviets said that the activity passed uneventfully and soon the new panel was fully deployed. The panel assembly was said to be 10.6 m long with an aggregate effective area of 22 m^2. The Soviets said that if a fault was detected the whole assembly could be retracted and replaced. As more modules are launched to the station and electrical power needs to be increased then more panels will be flown to the complex.

Before returning to Mir's interior the cosmonauts placed cassettes with various sample materials on the exterior of the station for exposure to space. These samples, which include various structural and heat-shield materials, will probably be collected during a later EVA.

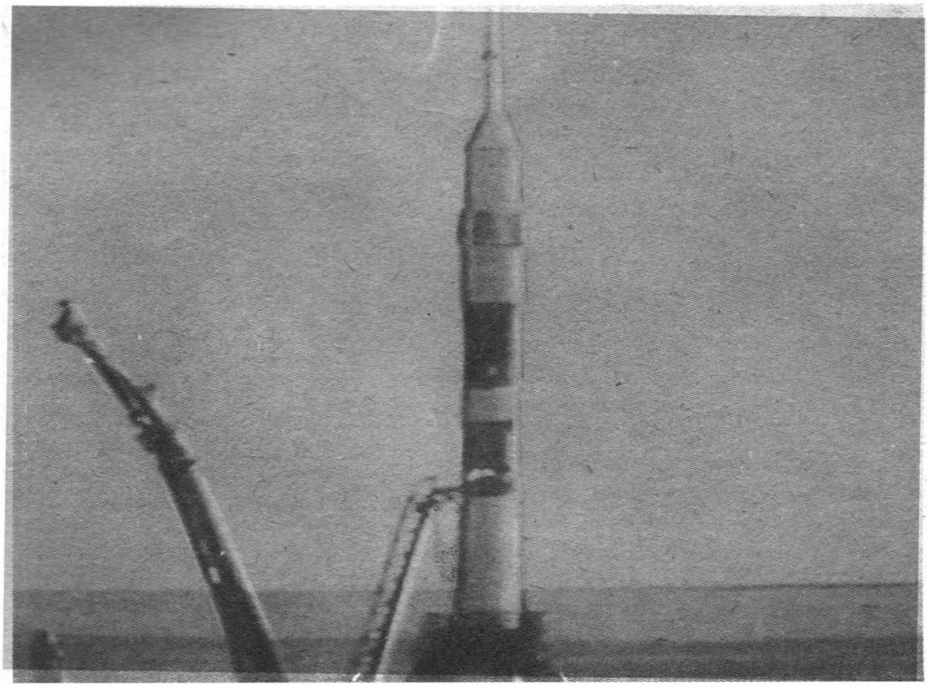
The cosmonauts returned inside after an EVA which had lasted three hours and 15 minutes. TASS praised the cosmonauts' "high professionalism and skill".

Working on Mir

On June 19 TASS revealed that the medical group on Earth was "closely following the state of health" of the men and said that a comprehensive check of their cardiovascular system was being conducted with the Gamma-1 apparatus.

During the next few days the men were involved in various station maintenance opertions and experiments with the Kvant. An earlier report said that the observatory on Kvant had been successfully pointed to a specific point in space with an accuracy of one arc minute which the Soviets said was some ten times better than originally expected. The observatory included four X-ray telescopes and a Soviet/Swiss UV telescope.

Other reported activities included the replacement of a unit in their on-board computer complex and scientific experiments on the Korund smelting furnace, the Biostoykost installation to make polymers and the Yantar installation to deposit thin coatings of metal in



Soyuz TM-3 just before launch on July 22. Note the photographer on left in this shot.

weightless, vacuum conditions.

At 0020 GMT on July 19 Progress 30 separated from the Kvant docking unit and was later commanded to a destructive re-entry in the upper atmosphere where it burned up.

As the cosmonauts in orbit continued their experiments, work at the Baikonur Cosmodrome was reaching a climax for the despatch of the Soviet/Syrian three-man Soyuz TM-3 space mission. The flight was the first in over three years to feature a guest cosmonaut.

Soyuz TM-3 International Mission

Between March 1978 and May 1981 nine Soyuz spacecraft carried guest foreign cosmonauts to Salyut 6. Two further flights were made to Salyut 7 in June 1982 and April 1984 carrying cosmonauts from France and India. The Salyut 6 flights arose from a 1976 Interkosmos agreement whilst the two other flights were derived from invitations to the guest country by the Soviet government.

The flights had two purposes: switching of Soyuz spacecraft to allow the resident crew of the Salyut to have a "fresh" spacecraft, and politics. Although the Soviets did not always switch spacecraft on international missions the flights always generated a great deal of publicity.

In late 1985 it was revealed that two Syrian Air Force pilots Mohammed Faris and Munir Habib, had arrived in Moscow to train for a flight to a Soviet station. Other flights have since been announced.*

Faris and Habib were assigned to flight teams in late December 1986. The prime crew consisted of Soviets Alexander Viktorenko and Alexander Alexandrov with Faris and the reserve crew of Soviets Anatoli Solovyov and Viktor Savinykh with Habib. The launch date was set as July 22 and the flight was due to end on July 30. The cosmonauts were to fly to Mir, conduct experiments with the main crew for some days and then return to Earth on Soyuz TM-2 leaving their TM-3 craft for the resident crew.

The launch occurred at 0159 GMT on July 22, just after dawn at the Cosmodrome. The event was shown live on TV for the Soviet Far East and in Syria. The new cosmonaut commander of Soyuz TM-3, Viktorenko, had the call-sign of "Vityazi" (Knights).

On the fourth and fifth orbits of Soyuz TM-3 a double impulse manoeuvre was conducted on command from Earth and at 1020 GMT the cosmonauts were allowed to sleep.

Early the next day another manoeuvre was made to increase the perigee of the orbit from 236 km to 304 km. Apogee was 365 km, the Soviets said, therefore there would have to be another manoeuvre before the final

Laveikin (centre) and Viktorenko at the Soyuz TM-2 landing site.

*Early in 1988 a Soviet/Bulgarian flight will be made to Mir. The Bulgarian will probably by Alexander Aleksandrov and his reserve will be Krasimir Stoyanov. In late 1988 Frenchman Jean-Loup Cretien will fly to Mir for a long-duration flight of about one month where he will conduct an EVA. Future flights will include an Afghan cosmonaut and possibly an Austrian cosmonaut.

approach to the Mir complex could begin. The two-day approach is now standard practice for the Soyuz spacecraft and saves fuel.

The two cosmonauts on Mir were now working a different timetable to accommodate the international flight. The men were to retire to sleep at 1530 GMT on July 23 to be awake for the early morning docking of the international crew.

"The men had earlier transferred into the spacecraft and bolted themselves in. Mir/ Kvant was then commanded to rotate 180 degrees and the spacecraft was manoeuvred to dock with the vacant port."

The final approach of Soyuz TM-3 was shown live on TV in Syria and also in the Soviet Union on the new breakfast TV show there. The Syrian delegation at the Flight Control Centre watched intently as the TV showed the initial contact of TM-3 with the Kvant docking unit at 0331:23 GMT, July 24. The hard docking itself took place with a force of some 20 tonnes.

The hatches between Kvant and Soyuz TM-3 were opened just before 0500 GMT (with the help of a crowbar due to a slight pressure difference between the two craft) and the Syrian cosmonaut was the first to float into the station. He was greeted warmly by Romanenko and Laveikin and he wished the men "Dobroye Utro (Good Morning), Salam."

During the live TV broadcast of the meeting Vladimir Shatalov, the former cosmonaut and now the head of the training centre near Moscow, said that the TM-3 Flight Engineer, Alexandrov, would stay on the complex and Alexander Laveikin would return in Soyuz TM-2. Shatalov said that medical specialists had detected changes in the cardiogram of the TM-2 Flight Engineer and that Mir's facilities "were insufficient for conducting a more profound, more thorough analysis". Shatalov stressed that there had been "no serious mis-givings" about the health of Laveikin but with a long flight ahead it had been considered best to bring him home. Alexandrov had been given a month's training on the Mir mock-up to enable him to take over.

In a subsequent press conference, Viktor Blagov, the deputy mission controller, said that the international crew would return home in Soyuz TM-2 and would leave TM-3 for the new pair of Romanenko and Alexandrov.

Blagov revealed from now on it was planned to make both full and partial replacements of crew members of the Mir main crews. He said that Laveikin's was "a planned replacement" but admitted that the cardiologists had some reservations, although insignificant ones, about the health of the cosmonaut.

In space, the five cosmonauts settled down to a meal and an exchange of telegrams w h the Soviet and Syrian leaderships.

Soviet/Syrian Work in Space

Syrian specialists had named their experiments, which encompassed Earth observations, medical checks and technology, after ancient cities of Syria.

In the Euphrates experiment the cosmonauts conducted visual, photographic and spectrometric surveys of Syrian territory. The data will be used for surveys for minerals and water as well as pollution in the atmosphere and coastal regions.

The Bosra experiment involved studies of the upper layers of the atmosphere and ionosphere to perfect mathematical models.

In the Palmyra experiment seven pairs of syringes were used to combine two substances to obtain a crystalline structure similar to bone tissue. On the ground the substance will be tested. The Soviets said that the synthetic substance was comparable to human dental and bone tissue.

There were two reported experiments in the Kristallisator unit. Under the Kasyun codename an aluminium-nickel alloy was smelted and in the Afamia experiment a monocrystal of gallium was obtained.

The cosmonauts used the Ruchei (Brook) equipment to clean, by electrophoretic means, several batches of gene-engineering interferon and anti-flu preparations and also used the Svetlana equipment (which is mounted on Kvant) to separate active micro-organisms producing antibiotics for the needs of stock rearing.

On the medical side the cosmonauts conducted the Ballisto experiment to record the activities of their hearts and other medical parameters. The aim of the medical tests was to gather further data on the early days of the body's adaptation to weightlessness. They also continued the Anketa (Questionnaire) experiment which saw the men answer a set series of intricate questions before, during and after the flight to assess their state of mind. This experiment has been a standard one for international flights since Soyuz 28.

From the start Viktorenko, who was making his first space mission, seems to have adapted very well to weightlessness, prompting a question about his success at the post-flight press conference when the cosmonaut himself attributed it to ten years of training. Faris, the commander said, suffered slightly initially but by the second day was working well. Alexandrov, of course, had flown in space for over 149 days in 1983.

At one point the cosmonauts jokingly asked for more hours in the day so that they could complete all the work. A Soviet report said that the men were working generally ahead of schedule. At one point Romanenko admitted to some confusion about there being three cosmonauts aboard Mir with the first name of Alexander!

The cosmonauts held two press conferences, interspersed with their experiments, answering questions which had been sent to them in advance. In one of them Romanenko said that he would like to fly with Faris on an international mission to Mars; Faris agreed that he would accompany the veteran Soviet cosmonaut. Faris had brought with him to the station a number of momentoes, including political items and Syrian wheat. The cosmonaut refuted suggestions that he was simply a passenger on the flight and claimed that he was making an active contribution, citing the Euphrates experiment. Early in the flight, Vladimir Shatalov had said that the training cycle for international flights, which is currently 18 months, might be reduced as more experience was gained.

Descent to Earth

At 1700 GMT on July 29 Soviet radio began a broadcast covering the preparations for the return of Soyuz TM-2. After bidding an emotional farewell to Romanenko and Alexandrov, cosmonauts Viktorenko, Laveikin and Faris transferred into Soyuz TM-2. At 1708 GMT the hatches were closed. TV showed the departure later.

"There had been 'no serious mis-givings' about the health of Laveikin but with a long flight ahead it had been considered best to bring him home."

After a final check of the spacecraft systems, Soyuz TM-2 was undocked from Mir's front docking unit at 2034 GMT. On the second orbit after undocking the Orbital Module was cast off. It was later revealed that the original landing was to have taken place at 2330 GMT but that the event had been postponed for two orbits due to floods at the primary site due to "abundant summer rains". One previous Soyuz mission had landed in a lake (Soyuz 23) and the Soviets had no desire to repeat the experience of that flight!

The Soyuz engine was ignited for 210 seconds to initiate the descent to Earth. The search and rescue teams had left their bases about an hour before the scheduled landing time.

In Mission Report, August 1987 p.282, a sentence was inadvertently altered to give a mis-leading statement "For the next days the two cosmonauts spent time on routine maintenance, medical tests and activating the Kvant module" (col 3, para 4) should have read " instead of activating the Kvant module"

Dawn was just breaking as they departed. The helicopter pilots were the first to spot the hugh parachute containing the Soyuz TM-2 descent cabin. The first indications of the trajectory gave concern to the pilots – winds were blowing the capsule towards a small settlement.

However, the winds carried the capsule over the settlement and the cosmonauts landed safely in a field at 0104 GMT July 30 some 2 km from the nearest building. The site was near the town of Ladyzhenko, some 140 km north-east of Arkalyk.

The landing was covered live on radio. First out of the downed capsule, which was charred on one side and lying on its side, was Viktorenko, followed by Faris. The two cosmonauts were said to be in "jaunty spirits". However, the long-stay Flight Engineer, Laveikin was said to look "pale". Laveikin said that he had not enjoyed leaving Mir and would gladly return. The cosmonauts were interviewed in special lounge chairs brought for them by the rescue services.

They were later taken by helicopter to Arkalyk and then flown to the Baikonur Cosmodrome. Laveikin had to be helped off the airplane by medical staff and a reporter commented that he looked like a man who had been away from Earth for half a year and that the experience placed "a heavy burden" on the man.

Redocking of Soyuz TM-3

At 2328 GMT on July 30 Romanenko and Alexandrov, the new "Taimirs" (Romanenko's call-sign), undocked their Soyuz TM-3 spacecraft from the Kvant module. The men had earlier transferred into the spacecraft and bolted themselves in.

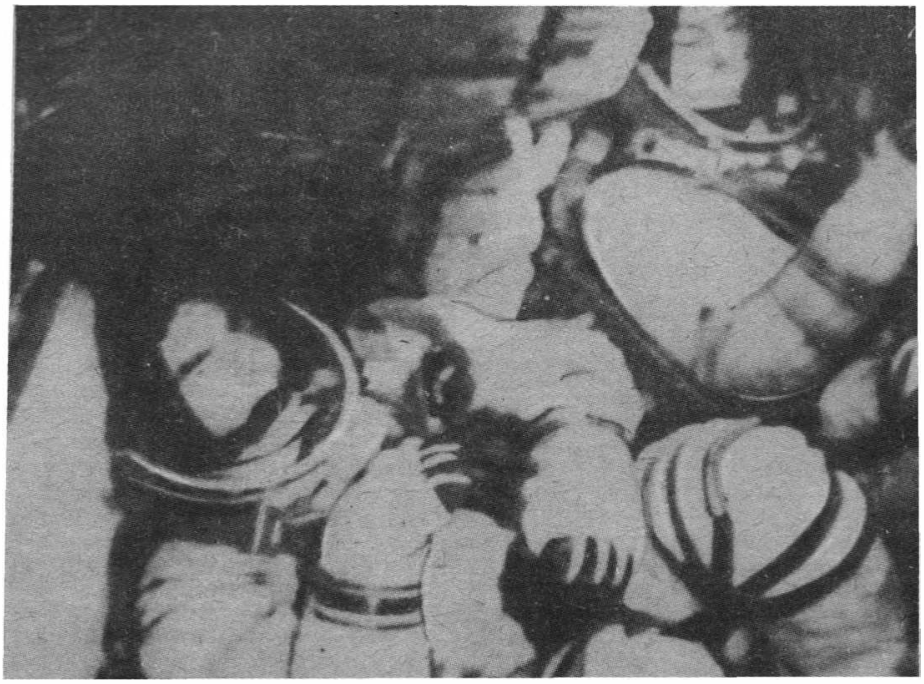
Mir/Kvant was then commanded to rotate 180 degrees and the spacecraft was manoeuvred to dock with the vacated front docking port at 2348 GMT. There appears to have been no live coverage of the event because it occurred in the early morning Moscow Summer Time.

A report issued on July 31, during a press conference at Baikonur for the TM-3 cosmonauts, said that no problems had been revealed with Laveikin's cardiovascular system. Further study of the cosmonaut would be done at the All-Union Cardiology Unit in Moscow, the Soviets said.

Soviet TV crews were allowed to see Laveikin in his room wearing special leggings to counteract the unpleasant sensations of standing. The cosmonaut said that he had come to know every nut and bolt, every panel, every cable and instrument on Mir and that he was disappointed when the doctors told him to come home. "And you can't disobey doctors' orders, can you?".

It was later revealed that towards the end of Laveikin's stay in space changes in the rhythm of his heart whilst under physical stress loads had been noted and that it was difficult for the specialists to forecast further changes in the rhythm.

Doctors had rejected outright any possibility of treatment in space because of possible side effects of the drugs which would need to be used. The cosmonaut himself felt no unpleasant sensations, specialists noted, but they did advise Laveikin on his professional activities, physical training and work-and-rest regimes. The tests to try and determine the cause of the irregularity were due to be carried out about two months after the cosmonaut's return to Earth.



Soyuz TM-3 commander Viktorenko (left) and flight engineer Alexandrov prior to launch.

Working on Orbit: A New Cargo Ship

The only reported activities of Romanenko and Aleksandrov in the first days of August involved station maintenance activities, biological studies and more observations of the supernova in the GMC with the Kvant X-ray telescopes.

At 2044 GMT on August 3 Progress 31 was launched from the Baikonur cosmodrome to fill the Kvant docking port vacated by the Soyuz TM-3 spacecraft on July 30. The cargo spacecraft docked with Kvant at 2228 on August 5 and the next day the cosmonauts began unloading the cargoes it had delivered.

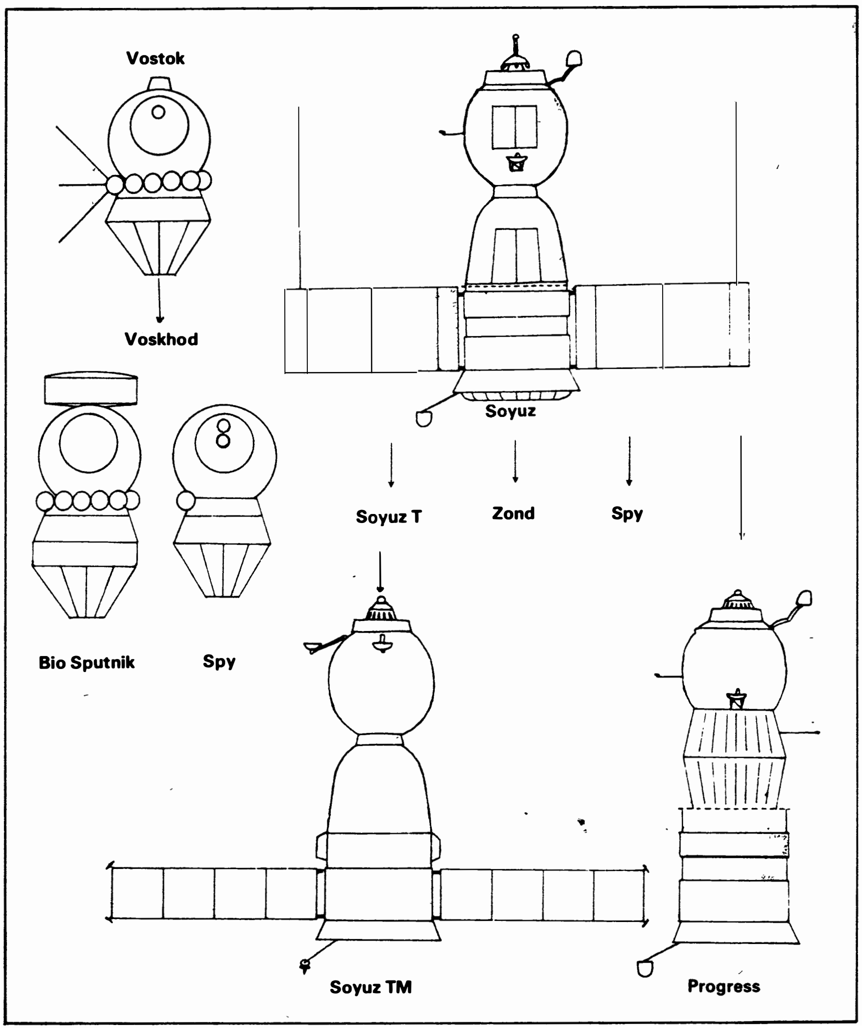
As they began to install the delivered equipment in Mir and Kvant reports of their activities became sparse and low-key. The next few days saw the two men continue unloading Progress, conducting observations of various targets with the X-ray telescopes and conducting medical experiments.

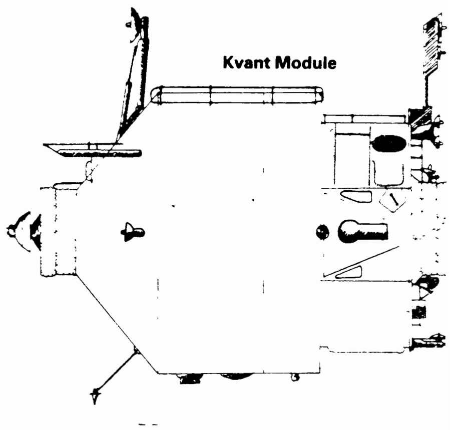
On August 12 the men prepared the Korund furnace for a routine experiment to obtain crystals from a semiconducting material with improved properties. They also made more astrophysical observations.

By August 17 the cosmonauts had begun another cycle of observations of Soviet terroritory which would last for several months, the Soviets said. The experiment involved, amongst other things, measurements of the atmosphere over a Kazakh power station to monitor air pollution. The work was being alternated with more astrophysical observations.

On August 23 it was reported that the men were observing the Pacific Ocean and the Sea of Japan to collect data to help forecast the approach of typhoons.

On the last day of August the cosmonauts conducted an emergency drill when, at an unspecified moment, the men were told to evacuate the station. They quickly donned their spacesuits and transferred to Soyuz TM-3 and sealed themselves in. The drill over, the cosmonauts returned to Mir and continued their scientific work. The cosmonauts had practiced returning home in an emergency but they are not due to return home on schedule for a while; Soviet commentators revealed as August gave way to September that the cosmonauts would return to Earth in December and that they would be replaced by another Soviet crew, probably cosmonauts Vladimir Titov and Alexander Serebrov, who may try for a full year in space.





The Kvant module (above) was originally intended to dock with Salyut-7 at the front docking unit and had to be extensively modified when it was decided to delay its launch and dock it instead with the Mir rear port. In this new configuration, a Progress service module docks at Kvant which had to be equipped with fuel lines to carry fuel from Progress into Mir

The progressive development of Soviet spacecraft is illustrated (left) in this diagram which shows the 'parent' craft Vostok and Soyuz and other craft which have arisen from them.

Soviet Shuttle for Space Station Role

The Soviet Union's space programme relies to a large extent on technologies developed 15 to 20 years ago. Their philosophy has always been to gradually improve existing equipment, rather than design completely new hardware. However, with the new Energia launcher and the soon-to-be introduced Soviet shuttle, the Russians are introducing space hardware of a truly new design into their manned programme for the first time since 1971. In that year, the last of a family of basic designs was put to the test in the form of a space station, Salyut. *Lucien van den Abeelen* **here reviews past and future trends in Soviet space hardware and highlights the transition that is now gradually taking place to a new era of space exploration.**

Vostok, Soyuz and Salyut

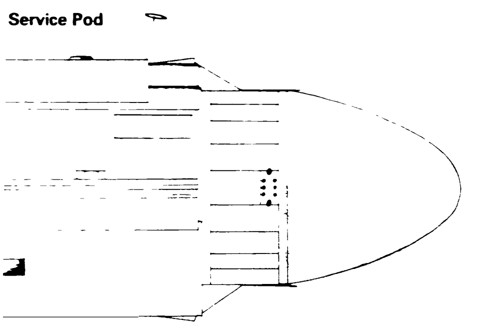
The Soviets have only ever designed three manned vehicles. This trio has proven to be reliable, capable of relatively easy modification and to be the backbone of an aggressively expanding space programme. The three 'parent' craft were Vostok, Soyuz and Salyut. After successful missions as craft in their own right, each of them was developed further, entering a second and sometimes third career. Many of the derivatives are still flying today.

After six manned flights, Vostok became Voschod. Only in the last few years have the Soviets admitted that Voschod was a modified Vostok. The vehicle later became an animal-carrying research satellite named Biosputnik and is still used today. Another version still frequently flying is the reconnaissance/spy Vostok, capable of returning high resolution film.

The Soyuz in its present form is the third generation of a craft introduced twenty years ago. Although its debut ended in the tragic death of cosmonaut Vladimir Komarov, and there were several docking failures, Soyuz has carried out more than 50 manned missions. Soyuz gave rise to Zond and the Progress freighter and later to the 'T' and 'TM' versions. A spy version with real-time imaging capability is also in use.

Salyut-1, launched in 1971, was to become a successful design, the basis of which is still likely to be in use 25 years after its inauguration. Though Salyut had its problems too, it was improved considerably. At first it was only a lab for short-term use, then capable of being resupplied, and finally, being expanded.

SOVIET SCENE



Mir

Today, we recognise the Salyut design in all elements that are to make up the Mir infrastructure of the near future. The core station itself, the Kvant module, the Earth-resources, astronomical, biological and technological modules and their supportcraft all share the basic Salyut design.

Mir was in the pipeline for a long time. Ever since the first launch of Salyut, the Soviets declared their intention to orbit 'large orbital research complexes, to be assembled from separately launched elements.'

It is however, surprising that it took 15 years from the prototype Salyut unit to the first application of the idea with the Mir station. The Soviets have indicated that Mir can be used for 'about ten years' with continued changes of configuration as modules are added and replaced, dictated by scientific demands and the advance of space technology. In a recent publication, it was emphasized Mir was only a prototype of a future modular space station [1]. It may be therefore that there will be only the one Mir core station. A decade seems to be the average time necessary to develop and execute a new space project; so once Mir ends its useful time in orbit, the next generation of station elements may be ready to enter service. The current modules are going to play a major role in expanding the Mir station. Not only will they enlarge the crew and laboratory room, they will double as space tugs, free flyers and freighters. The booklet indicated that the modules were to replace the Progress craft as the means of resupplying the station.

Experimenting with adding modules to a station in orbit was begun on Salyut 7; it received Cosmos 1443, which was manned for some time and used the first, and up till now only, heavy return module. Cosmos 1686 is still attached to Salyut 7, to be visited once more in a few years time.

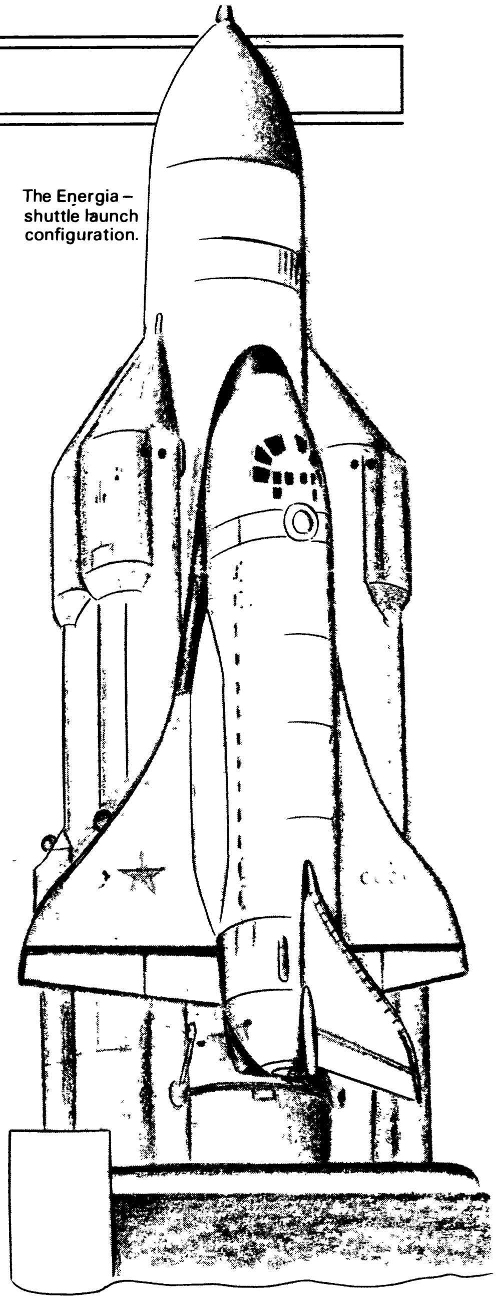
The first module to dock with Mir was Kvant, a dedicated module, housing equipment for astrophysical research. However, the design of Kvant is not likely to be seen again. Kvant was originally intended to dock with Salyut-7 at the front docking unit, as the rear unit was needed for the Progress craft. After the Soviets experienced problems with both Kvant (during assembly) and Salyut (the power breakdown), it became clear to them that it would be wiser to delay Kvant until the Mir station was in orbit.

However, for attachment to Mir, Kvant would have to be extensively modified. The module could not be docked at the front, because this port is to act as the primary unit for all modules to be added to the core station. Neither could it be docked at one of the side ports, as Kvant houses gyroscopes for pointing the complex, and these were designed with the straight-line Salyut-Kvant configuration in mind. Kvant at a side port would obviously not be as effective. So it would have to be docked at the rear port, but this meant Kvant had to be equipped with fuel lines to carry fuel, pumped from Progress, into Mir. These modifications took longer than expected, further delaying the launch of Kvant. This is the reason Kizim and Solovyov returned early from the Soyuz T-15 mission. As Mir was not equipped with scientific instruments and there would be no add-on module, the couple had nothing more to do on board Mir.

Energia and the Soviet Shuttle

Although Mir, in effect, relies on old technology, Energia and the Soviet shuttle are true innovations. Energia will play a major role in the entire Soviet space program and will be the key to developing true large-scale orbital complexes. With 4000 tons thrust it is more powerful than the US Saturn V rocket, and it seems the May 15 configuration is not the end of the line. On its first flight, Energia employed four strap-on boosters, running on kerosene/oxygen. There is room for four more on the central core. Thus, Energia will be able to put into orbit much heavier structures than the basic 100 ton version. With eight boosters and an adapted core with third stage and payload on top, Energia could put into orbit modules with an 8 m diameter and a mass of up to 200 tons. Sources have claimed this kind of station has been under development for years; it may become a reality within a decade [2].

In the four booster configuration, Energia can carry to orbit the Soviet shuttle. Expected to fly within a year, it will play a generally different role than the US Shuttle does. It is expected to be used for taking modules to the Mir station, and maybe for bringing old ones back to Earth for refurbishment and re-use, or to examine the influence of space on spacecraft structures. With a payload bay diameter reported to be larger than the US Shuttle, the Soviet one could bring back Salyut-7 after its solar panels are removed!



The Energia – shuttle launch configuration.

Energia may also launch the flotilla of science spacecraft to Mars in the nineties. Inside the payload bay, these craft could be subjected to an in-orbit checkout before departing for their planetary destinations. Servicing and in-orbit repair are other obvious uses, already successfully demonstrated by American orbiters.

The process of adding new technology to an existing stable of reliable launch vehicle workhorses, and the self-confidence apparent from it, is leading the Soviet Union into the number one spot of the team of space-faring nations. In contrast with the lack of activity on the part of the United States after the Challenger and subsequent accidents and t[illegible] turmoil within NASA, the Sov[illegible] seem to know where they are going with their space programme.

References
1. 'From Salyut to Mir', *Novosti*, 1987.
2. *Aviation Week and Space Technology*, June 16, 1980, p.26.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Liquid Booster Design Studies for US Shuttle

NASA has selected General Dynamics and Martin Marietta to negotiate for conceptual design studies of liquid-fuelled rocket boosters proposed for use on the shuttle and future launch vehicles.

Two contracts, each valued at approximately $2.5 million, will involve nine month parallel studies of both pressure-fed and pump-fed liquid fuel rocket boosters (LRBs). Both contractors will develop a recommended design for each system.

Marshall Space Flight Center will serve in a lead capacity on the project in cooperation with NASA's Johnson, Kennedy and Langley centres. JSC will investigate the booster interface with the overall shuttle system, while KSC will evaluate LRB effects on existing launch and vehicle assembly facilities and Langley will support evaluation of aerodynamic and aero-thermal dynamic data generated at Marshall.

Study results by summer 1988 could lead to replacement of the current solid propellant booster system and aid in the selection of configurations for future NASA advanced launch vehicles.

The 1986 report of the Commission on the *Challenger* accident called for a fundamental change in the US space programme, namely to move away from the almost total reliance on a single launch system.

The LRB studies will evaluate various booster configurations and propellant combinations to establish potential designs. The analyses will include assessments of performance, systems safety, reliability and integration of the LRB with the current Space Transportation System and existing launch facilities, recovery and reusability, and both operation and development costs.

Other issues to be assessed include techniques for recovery of the liquid rocket boosters, salt water exposure damage control and cost effectiveness of recoverable versus expendable systems.

Results of the LRB studies should be available next summer to support NASA management decisions regarding possible LRB implementation as a replacement for the current solid propellant booster system. Study results could also aid future agency decisions regarding the planning and configurations selected for advanced launch vehicles.

Requests for proposals for LRB designs were issued in May. In addition to the two firms selected, three other firms submitted proposals: Boeing Aerospace, Teledyne Brown Engineering and United Technologies.

Glavcosmos Spreads Its Wings

The two-year-old Soviet organisation Glavcosmos (the name stands for the Main Administration for the Creation and Use of Space Technology for the National Economy and Scientific Research) is to replace Intercosmos in its role of organising the USSR's international cooperation in space.

In its early days the Moscow-based Glavcosmos was solely responsible for handling the commercial side of Soviet space operations, notably the marketing of the Proton booster, (*Spaceflight*, December 1986, p.424). With the strictly commercial aspects of Proton launches now handled by V/O "Licensintorg", which is also located in Moscow, Glavcosmos concentrates on the wide-ranging technical matters of international cooperation, including the use of space hardware on a commercial basis. ***Theo Pirard*** here reviews the activities of Glavcosmos which fall in five main areas:

1. Scientific exploration with interplanetary probes, such as the Phobos programme to explore Mars and its moons, and payload opportunities offered or sold on recoverable Cosmos capsules, on Mir-Kvant modules, on manned Soyuz space flights, or on Vertikal sounding rockets.
2. Remote sensing operations with the sale of data and photographs recorded by Meteor-Priroda and Cosmos automated spacecraft or from the Mir-Kvant complex.
3. Telecommunications and navigation by satellites with the lease of C-band and Ku-band transponders from Gorizont-Statsionar spacecraft.
4. Microgravity utilisation for materials processing with payload opportunities provided by automated Cosmos spacecraft and by manned Mir-Kvant space flights, and the lease of Soviet systems for crystals growth, for pharmaceutical products and new materials.
5. Manned space flights with the possibility of foreign cosmonauts on board Soviet spacecraft coming back in force after the first phase of Intercosmos Soyuz flights (1978-1984) involving Salyut 6 and 7 stations. Phase two began with the Soyuz TM3 mission of two Soviet and one Syrian cosmonaut (*Spaceflight*, August 1987, p.281 and this issue p.373).

The next international flights organised by Glavcosmos will be in 1988. In the meantime the Mir-Kvant station will receive a lateral module for remote sensing operations and be inhabited by two new long-duration crew members, Vladimir Titov and Alexander Serebrov, who are candidates for a one-year stay.

The Soyuz TM5 mission then follows with two Soviet and one Bulgarian cosmonaut, Alexander Alexandrov, who will spend one week in the Mir complex.

The Soyuz TM6 or TM7 mission with two Soviet and one French cosmonaut, Jean-Loup Chrétien, will spend one month in Mir and Chrétien will carry out EVA experiments with the deployment of structures outside Mir. Plans are in preparation through Glavcosmos for a Soviet-Afghan and a Soviet-Austrian mission in the 1990's. An agreement was signed on July 20 at Moscow between Afghan and Soviet representatives for the joint flight. Austria has just been invited by Moscow to send research specialists into orbit with Soviet cosmonauts and a similar invitation was made to the Indonesian authorities.

Rescue Terminal for Brazil

Canadian Astronautics Limited (CAL) has delivered the first Search and Rescue Satellite and Tracking (SARSAT) terminal to the Southern Hemisphere. The satellite ground station will ensure that survivors of aircraft and maritime emergencies are detected, located and rescued shortly after transmitting a simple distress signal.

It will be installed at Cachoeira Paulista, near Sao Paulo, and will provide rescue data to Brazil and its South American neighbours on completion of operational testing and a local training programme this autumn.

The Brazil SARSAT terminal is the seventh operational unit delivered by CAL with three additional units being assembled for Canada and the United Kingdom. The majority of the northern hemisphere is now within the coverage of ground stations provided by CAL or the USSR.

SATELLITE DIGEST – 206

Robert D. Christy

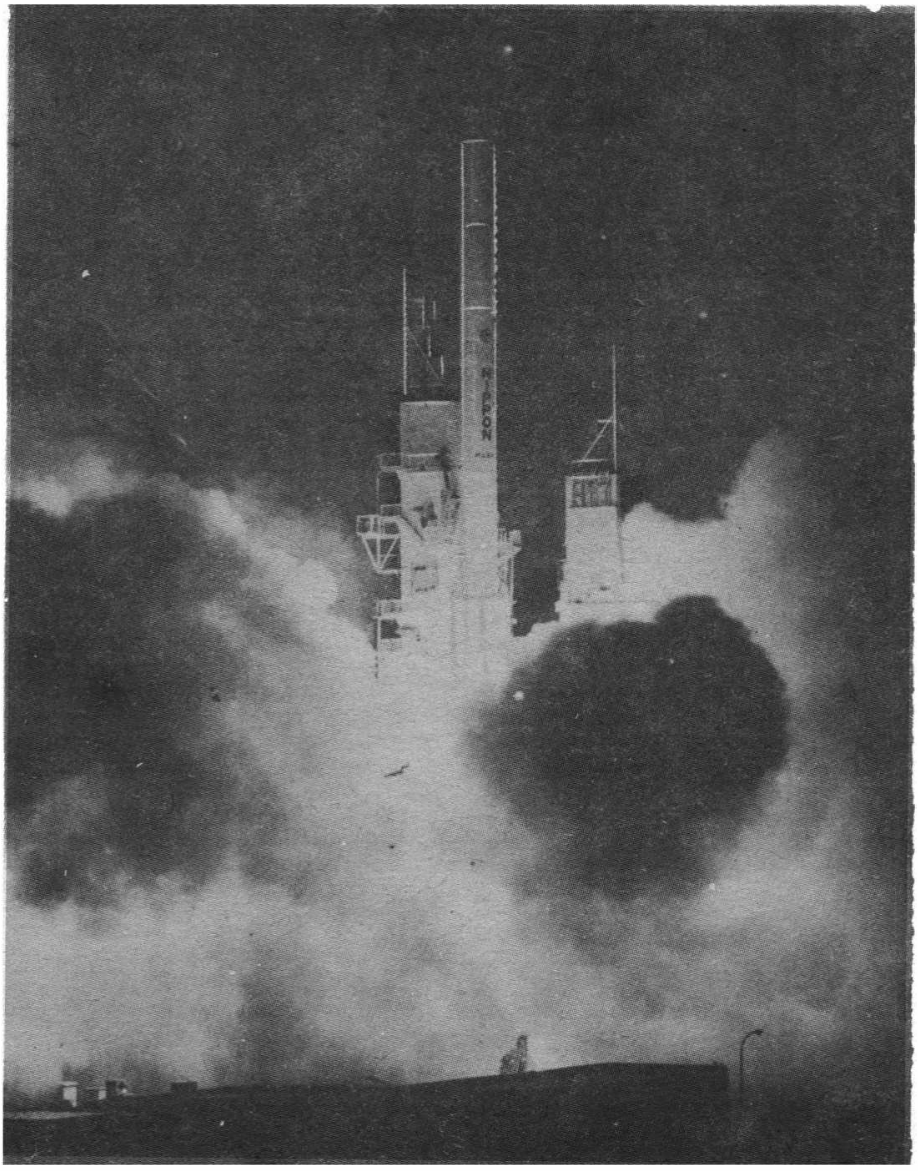
Continued from the September 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1849, 1987-48A, 18083.
Launched: 1850, 4 June 1987 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 605 x 39311 km, 708.90 min, 62.89 deg, then raised to 627 x 39728 km, 717.79 min, 62.90 deg to ensure daily repeats of the ground track.

COSMOS 1850, 1987-49A, 18095
Launched: 1448, 9 Jun 1987 from Plesetsk by C-1
Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 783 x 807 km, 100.82 min, 74.05 deg.

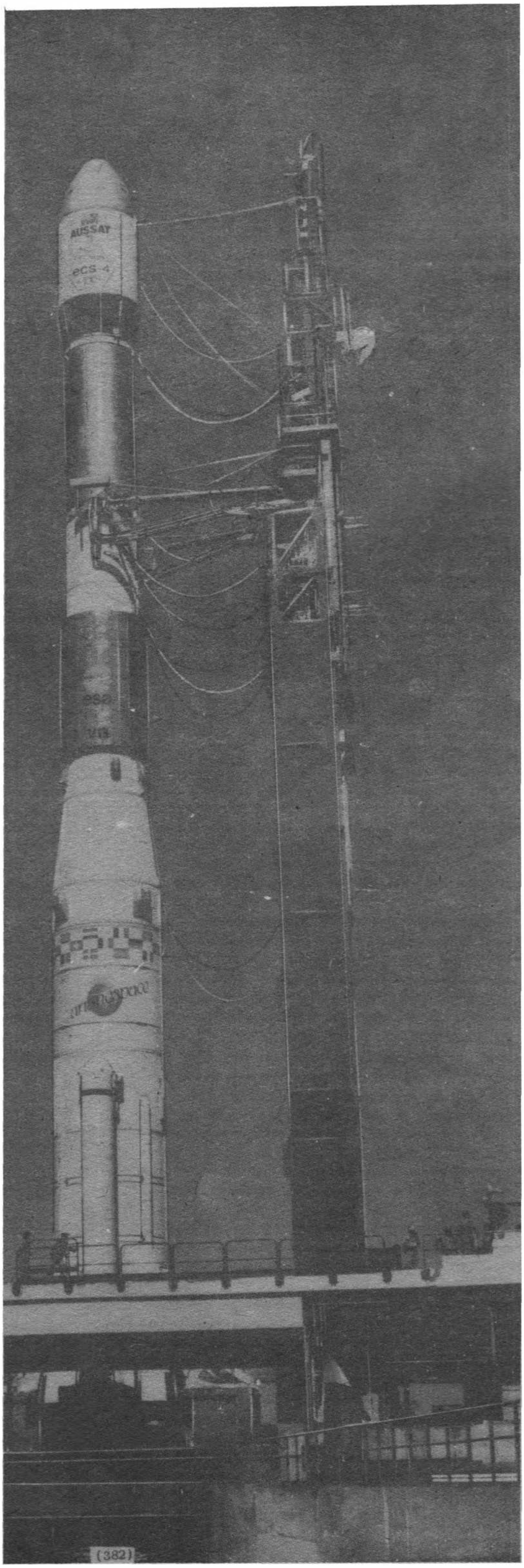
COSMOS 1851, 1987-50A, 18103
Launched: 0735, 12 Jun 1987 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the masimum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 598 x 39377 km, 710.09 min, 62.88 deg then raised to 600 x 39728 km, 717.23 min, 62.86 deg to ensure daily repeats of the ground track.

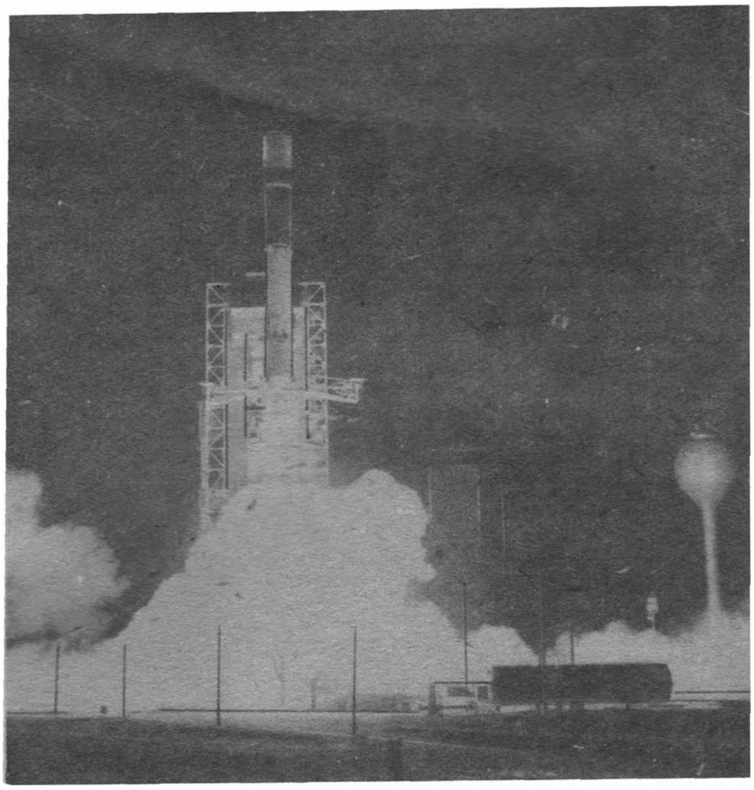


An experimental communications satellite designed to test mobile communications technology was launched into geostationary orbit by Japan on August 27. Designated ETS5, the satellite has an 18-month design life and is currently being used in a trial programme with a Japan Airlines Boeing 747-200F cargo aircraft. The launch (pictured above) was the first operational flight of Japan's H-1 three-stage launch vehicle. It was originally scheduled for August 10 but was delayed due to launch vehicle technical problems.

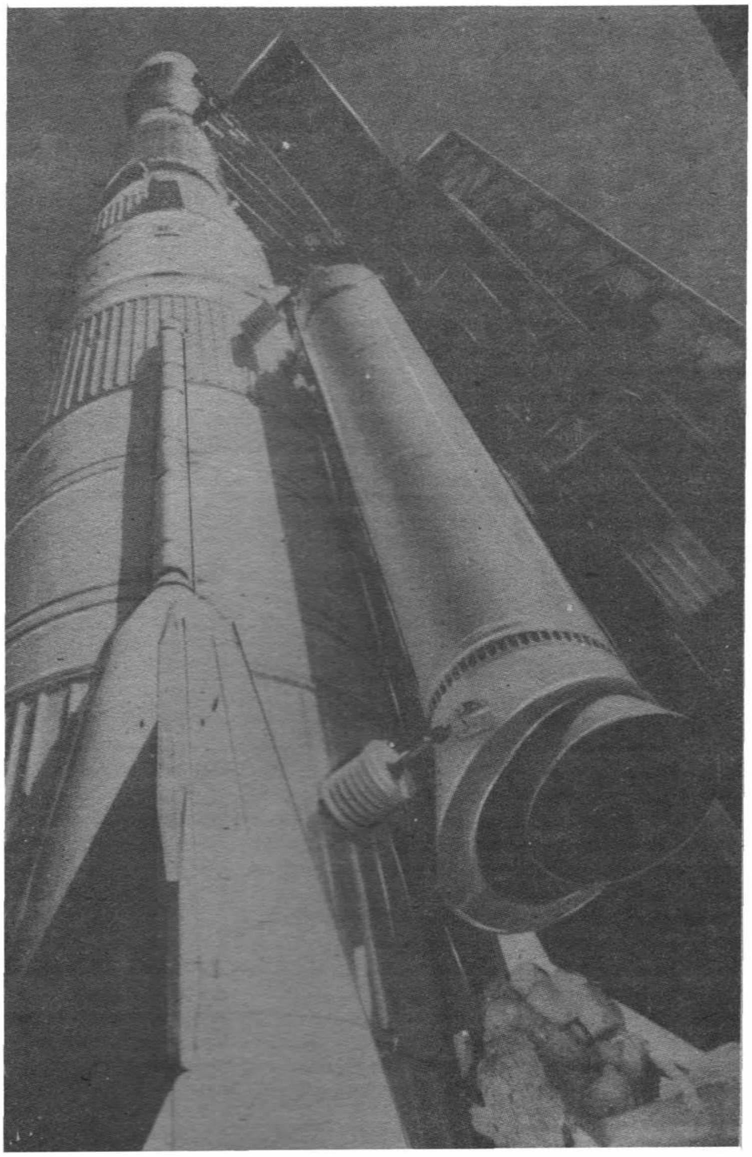
COSMOS 1852-1859, 1987-51A-H, 18113-18120
Launched: 1752, 6 Jun 1987 from Plesetsk by C-1.
Spacecraft data: Each satellite is probably spheroidal in shape, about 1 m long and 0.6 m diameter, and with mass approx 40 kg.
Mission: Single launch of eight satellites to provide tactical, point to point communications for troops or units in the field.
Orbit: 1388 x 1477 km, 114.54 min, 74.01 deg (lowest), 1473 x 1501 km, 115.74 min, 74.01 deg (highest).

COSMOS 1860, 1987-52A, 18122
Launched: 2133, 18 Jun 1987 from Tyuratam by F-1.
Spacecraft data: Combined satellite and final rocket stage, around 7 m long and 2 m diameter with a mass around 5000 kg. A slot-type radar aerial is fixed to one side of the body. Power is provided by a nuclear reactor.
Mission: Radar reconnaissance over ocean areas.
Orbit: 251 x 264 km, 89.66 min, 65.00 deg, maintained by a low thrust motor during the operational lifetime. On 28 Jul, at around 1600 GMT, the nuclear power source was boosted to a 901 x 966 km,





Ariane Flight 19, Kourou, French Guiana, September 15, 1987. *Left and below:* The Ariane 3 launch vehicle on launch pad No. 1 for the launch of the Aussat K3 and ECS4 communications satellites to geostationary orbit. *Above*: Just moments after lift-off. *Arianespace*



INTERNATIONAL SPACE REPORT

Continued from page 281.

104.04 min, 65.01 deg orbit to delay re-entry into the Earth's atmosphere.

USA 26, 1987-53A, 18123
Launched: 0238, 20 Jun 1987 from Vandenburg AFB by Atlas E.
Spacecraft data: Irregular cylinder with a single solar panel at right angles to one end. The length is about 6 m, and the diameter approx 2 m, and the mass is around 700 kg.
Mission: Defence Meteorological Satellite Programme vehicle, sending back weather images and other data for use by the US DoD.
Orbit: 840 x 859 km, 101.98 min, 98.84 deg.

COSMOS 1861, 1987-54A, 18129
Launched: 0741, 23 Jun 1987 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite, equipped with two radio transponders (RS-10 and RS-11) for worldwide use by radio amateurs.
Orbit: 985 x 1001 km, 105.03 min, 82.93 deg.

COSMOS 1862, 1987-55A, 18152
Launched: 1936, 1 Jul 1987 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 633 x 667 km, 97.79 min, 82.51 deg.

COSMOS 1863, 1987-56A, 18155
Launched: 1225, 4 Jul 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 357 x 416 km, 92.32 min, 72.88 deg.

COSMOS 1864, 1987-57A, 18160
Launched: 2200, 8 Jul 1987 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 961 x 1006 km, 104.83 min, 82.9 deg.

COSMOS 1865, 1987-58A, 18162
Launched: 1100, 8 Jul 1987 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 208 x 268, 89.28 min, 64.76 deg, manoeuvrable.

COSMOS 1866, 1987-59A, 18184
Launched: 1610, 9 Jul 1987 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period. On 27 July, its manoeuvring engine failed to shut down and used up all the propellant.
Orbit: Initially, 167 x 361 km, 89.80 min, 67.16 deg, then after some manoeuvring, propelled to an orbit of 234 x 1079 km, 97.89 min, 67.17 deg.

COSMOS 1867, 1987-60A, 18187
Launched: 1533, 10 Jul 1987 from Tyuratam by F-1.
Spacecraft data: Cylindrical, probably about 7 m long and 2 m diameter, equipped with solar cell panels and with a mass around 5000 kg.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 788 x 801 km, 100.77 min, 65.01 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1868, 1987-61A, 18192
Launched: 1402, 14 Jul 1987 from Plesetsk by C-1.

Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Not known, but probably military in nature. It is possible that a malfunction in the C-1 upper stage produced an incorrect orbit.
Orbit: 285 x 709 km, 94.60 min, 74.01 deg.

COSMOS 1869, 1987-62A, 18214
Launched: 0426, 16 Jul 1987 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Oceanographic satellite equipped with a sideways-looking radar and other remote sensing systems to return images of the world's sea-surface.
Orbit: 635 x 666 km, 97.80 min, 82.52 deg.

SOYUZ-TM 3, 1987-63A, 18222
Launched: 0159*, 22 Jul 1987 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried the visiting crew of Alexander Viktorenko, Alexander Alexandrov and Mohammed Faris (of Syria) to the Mir complex. It docked with Kvant at 0330 on 24 July 1987. For the return to Earth, Viktorenko and Faris teamed up with long-stay crew member Alexander Laveikin in Soyuz-TM 1, undocking at 2034 on 29 July and landing at 0154 the following day. On 30 July, Yuri Romanenko (the other long-stay crew member) and Alexandrov moved Soyuz-TM2 to Mir's extreme forward port.
Orbit: Initially 197 x 217 km, 88.57 min, 51.62 deg, then by way of a 231 x 297 km, 89.74 min transfer orbit to a docking with Mir in a 311 x 359 km, 91.18 min, 51.64 deg orbit.

COSMOS 1870, 1987-64A, 18225
Launched: 0900, 25 Jul 1987 from Tyuratam by D-1.
Spacecraft data: Possibly a cylinder with solar panels, approx 15 m long, and with maximum diameter around 4 m. The mass may be around 18 tonnes.
Mission: Remote sensing for Earth resources, and ocean surface studies using radar. Its work is probably complementary to that of Cosmos 1869 (above).
Orbit: 237 x 249 km, 89.40 min, 71.92 deg.

INTERNATIONAL SPACE REPORT

India Plans Spaceplane

A horizontal takeoff and landing, reusable space shuttle will be the main plan of the Indian space programme by early next century, according to Prof. S.K. Shrivastava, of the Indian Space Research Organisation, speaking in Bangalore, writes *Gerald L. Borrowman.*

The shuttle, currently being planned by organisations engaged in space sciences, would be necessary to carry out frequent manned flights in view of increased space applications in fields such as communications, meteorology and research.

One shuttle configuration under consideration by Indian scientists is a small 'Space Cab' with a two member crew complement.

Prof. Shrivastava also said that the recent loss of the Augmented Satellite Launch Vehicle (ASLV) had not caused a big set-back to the Indian space programme.

Japan Offers Tax Incentive

A new tax system for promoting basic technology research, space development and use has been introduced in Japan.

The system provides tax cuts to a purchaser of testing and research equipment. More facilities related to space development have now been added to the items on a qualifying list.

Among the items approved for FY 1987 were:

- Equipment for simulating the outer space environment – special environments, such as the high vacuum of outer space, in which cryogenic temperatures and solar rays are simulated in a large chamber to examine whether a rocket and its parts will operate normally.

- Equipment for inertial moment measuring.

- Equipment for testing three-axis attitude control.

- Equipment for outgassing and gas concentration measurements.

- Equipment for testing environmental adaptability and combustion of rocket engines.

When any of this equipment is purchased or produced, seven per cent of the acquisition cost of the asset, or equivalent, can be deducted from the corporate tax (the limit is 15 per cent of the corporate tax, or equivalent).

Chinese Satellite Launch

China put into orbit its second satellite in just over a month at the beginning of September.

It was launched on a Long March 2 vehicle from the Shuang Cheng-tsu site in north-west China at 7.15 GMT on September 9, according to *Geoffrey Perry* of the Kettering Group.

China 21, a recoverable spacecraft, went into a lower, more circular orbit than its predecessor, China 20 which was launched on August 5.

Gibson to Command STS-27

The commander of a five-man crew aboard the US Space Shuttle Atlantis for STS-27 is to be Robert L. Gibson. The mission, the second following the resumption of flight operations, will be for the US Department of Defense and is scheduled for the autumn of next year.

Joining Gibson on the flight will be pilot Guy S. Gardner and mission specialists Richard M. Mullane, Jerry L. Ross and William M. Shepherd.

Robert "Hoot" Gibson.

Gibson, an astronaut since 1978, was pilot on mission 41B in February 1984 and commander of 61C in January 1986. He has logged 337 hours in space.

Mullane, also an astronaut since 1978, flew as mission specialist on 41D

Guy S. Gardner.

in August 1984, logging almost 145 hours in space.

Ross, who joined the NASA astronaut corps in 1980, was a mission specialist on 61-B in November 1985 during which he took part in two EVAs totalling 12 hours in support of the EASE/ACCESS construction experiments.

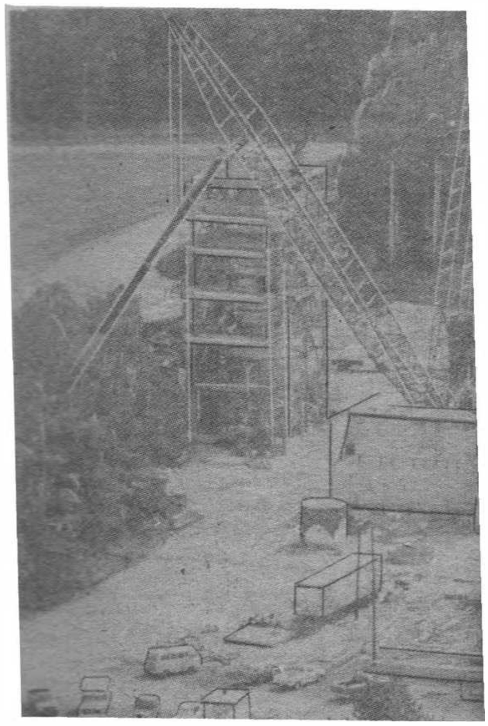
Gardner, an astronaut since 1980, and Shepherd, an astronaut since 1984, are both yet to fly in space.

The STS-26 crew, at present scheduled for a June 1988 launch, is Frederick Hauk (commander), Richard Covey (pilot), Mike Lounge and David Hilmers (mission specialists) and George Nelson (***Spaceflight***, February, 1987, p.52).

Third Ariane Launch Pad

Construction of a third pad at the Ariane launch site in French Guiana is due to start in the latter half of next year.

The new ELA-3 pad, completion of which is expected in the early 1990's, has been approved in preparation for the introduction of Europe's Ariane 5 launcher in the middle of the next decade.



INTERNATIONAL SPACE REPORT

Main Engine Acceptance Tests Begin

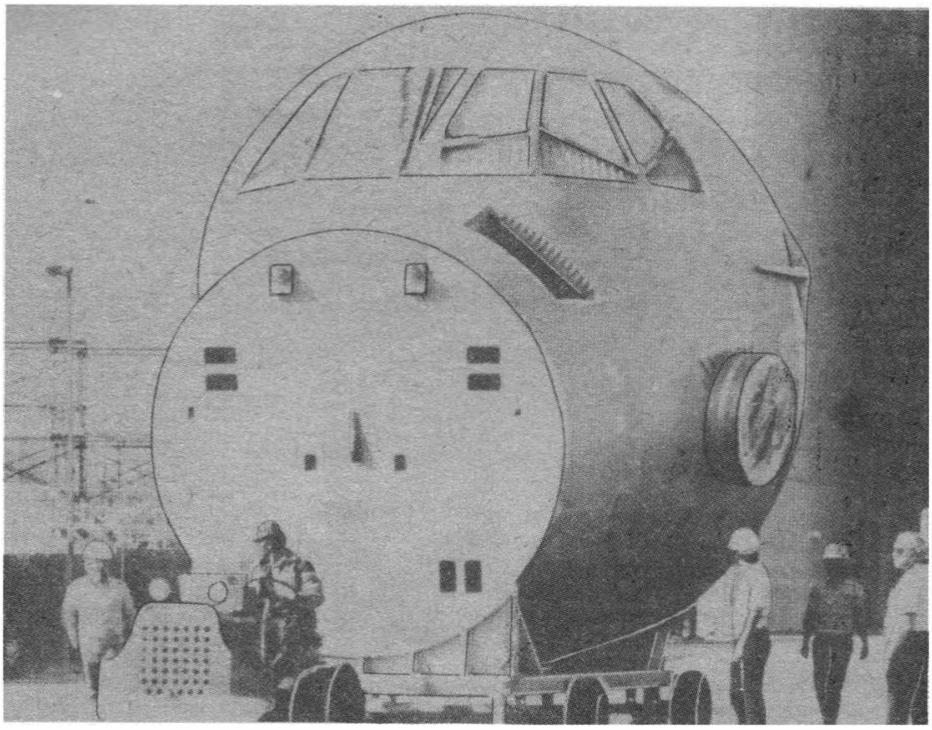
Acceptance testing has begun on the first of three Space Shuttle main engines earmarked for use on the June 1988 launch of the next Shuttle mission, STS-26.

Testing is being done at NASA's National Space Technology Laboratories in Mississippi by the Rocketdyne Division of Rockwell International, NASA's prime contractor for the Shuttle engines. The Marshall Space Flight Center in Huntsville, Ala., manages the engine programme for NASA.

The engines now incorporate several improvements made as a result of an extensive and on-going test programme. These changes include improvements to the electronic controller, valve actuators, temperature sensors, main combustion chamber, and various modifications to the turbopumps to improve life and operating margins.

During acceptance testing, three hot-fire tests, totalling about 770 seconds, will be run on each of the STS-26 flight engines. The tests include a 1.5 second ignition test, 250 second calibration test and a 520 second nominal mission simulation test. The 1.5-second test was successfully conducted August 11, on the first engine, number 2027, with the other tests on that engine taking place during September.

Testing has begun on the second engine, number 2022, and the third engine, number 2019. Acceptance testing on all the flight engines is expected to be complete next month (December).



A crew compartment spare to be used for the new shuttle orbiter, OV-105.

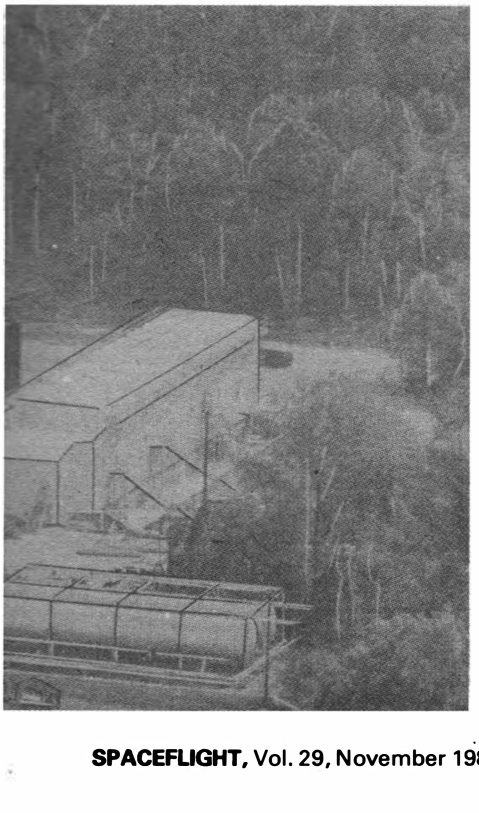
New Zealand Plans Aussat-B Role

The Telecom Corporation of New Zealand Limited and Aussat Pty Ltd of Australia have signed a Memorandum of Understanding (MOU) covering New Zealand involvement in the Aussat-B series of advanced domestic communications satellites planned for the 1990s.

Aussat-B will provide enhanced domestic telecommunications, data and broadcasting services within New Zealand and Australia beginning in the early 1990s. The Aussat-B series, comprising two satellites, is intended to replace the present Aussat-A series. The Aussat-B satellites are planned for launch in 1991 and 1992. Tenders for the construction of the two satellites (with an option for a third later in the 1990s) will be invited shortly.

Telecom will use up to four high-power Ku-band transponders on each satellite for telecommunications and broadcasting services. Each Aussat-B will feature a specially designed national beam covering all of New Zealand.

Telecom has also leased one transponder and part of a second on the Aussat A-3 satellite launched by Ariane V19 on September 15, 1987. This will enable preliminary tests of domestic telecommunications services to be carried out prior to the advent of Aussat-B in the 1990s.



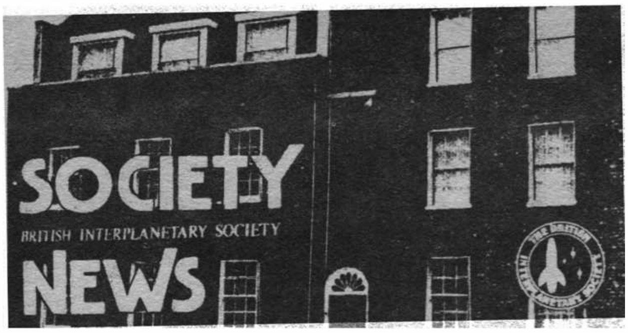
SRB Test Facility

NASA's Marshall Space Flight Center in Huntsville, Alabama, has completed construction of its Transient Pressure Test Facility which will be used for a series of Space Shuttle solid rocket motor tests scheduled to start early this month (November). The tests will verify the ignition pressure dynamics of the motor.

Run in conjunction with Joint Environment Simulator tests and full-scale motor firings being conducted at Morton Thiokol's Wasatch Facility in Utah, the tests are expected to lead to qualification of the redesigned motor.

In this photo, to the left is the access tower where the test article will be fired. The large building in the centre is the Refurbishment Facility where the test articles will be refurbished for subsequent tests.

NASA



SPACE '87 Exhibition

The Society held the largest space exhibition in its history at the joint venues of the Brighton Centre and the nearby Metropole Hotel, Brighton, between October 12 and 15.

The event, also rated as the largest space exhibition ever held in the UK, was the showplace for the space expertise of organisations and companies from all over the world, including the USA, USSR, Japan, France, Italy, Germany, the UK and major space agencies such as NASA and ESA.

The cover of the Official Catalogue of the SPACE '87 Exhibition, organised by the Society.

With over 200 UK companies now actively engaged in the space field with involvement in international programmes, it was also timely for a major space exhibition to be held in the UK. Recent uncertainty about the long-term funding of UK space activities has tended to detract from the creditable status which international recognition has gained for the UK in areas of its space expertise, and the Society's four-day ***Space '87*** Exhibition provided a valuable opportunity to help redress the balance.

With emphasis on the developments and applications of space technology, the Exhibition was an occasion for promoting commercial opportunities in the peaceful uses of space. The Society welcomes the growth of commercial opportunities in space operations, which it sees as a key factor in securing the long-term future of space exploration.

IAF Souvenir Brochure

In recognition of the work of the International Astronautical Federation in supporting peaceful international activities in astronautics and on the occasion of the 38th IAF Congress, held in the United Kingdom on October 10-17, 1987, the Society issued an eight page Souvenir Brochure of the event for Congress participants.

The publication records the main highlights of the week, including the Space '87 Exhibition held in conjunction with the Congress.

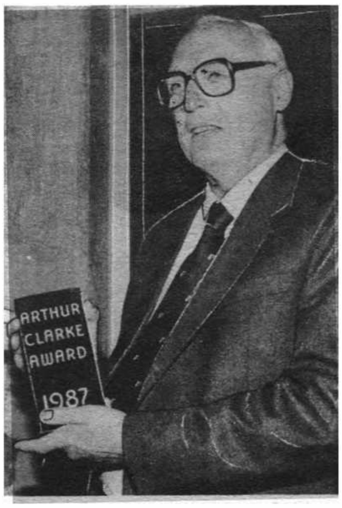
Advertising in Spaceflight

In response to enquiries received by *Spaceflight* from potential advertisers, a brochure has been printed giving details about the placing of quarter, half and full-page advertisements in the magazine.

The brochure has been distributed to known organisations with space interests and was available at the ***Spaceflight*** stand at the recent Space '87 Exhibition.

Members, who may be interested in taking up advertising space in ***Spaceflight*** or are able to bring the brochure to the attention of other potential advertisers either through their employment or other means, may request copies from the Society.

Education Award



The 1987 Arthur C. Clarke Award was presented to the Society's Executive Secretary, Mr Leonard J. Carter at the Award Banquet of the SEDS (Students for the Exploration and Development of Space) Annual Conference, in Houston, Texas, on August 8, 1987. The Award was made to the Society for its contributions to space education with Mr Carter as the nominated personal recipient. In his address, Mr Carter spoke of the ways in which the educational interests of the Society had developed from the earliest days. "At the end of the war, the Society entered a prolific decade of producing ideas and thoughts on every aspect of space additional to the 1945 contribution of Arthur C. Clarke on orbital relay satellites for space communications", he said. "This flowering of ideas was accompanied by the need for a programme of education from which resulting international interest led to a Congress being held in London in 1951 during which the International Astronautical Federation was formally inaugurated".

JBIS Author Receives Award

Our congratulations are offered to Dr. William A. Reupke on receiving the first place in the 1986 Honorarium Awards (individually sponsored category) of the Computer Sciences Corporation (CSC) Systems Group, USA, for his paper "Inertial Fusion Systems Studies and Nuclear Pulse Propulsion" which was published in the November 1985 issue of the Journal of the British Interplanetary Society (*JBIS*).

The CSC Systems Group established the competition in 1970 to stimulate and encourage their technical staff. The winning papers were selected by a panel of 12 adjudicators. We are pleased to note this further example of the prominence that ***JBIS*** receives internationally.

Building Extension Appeal

Welcome news for the Society's Building Appeal has been the recent notification of valuable bequests to the Society under the Wills of two persons, who in past years have been closely associated with the Society.

Mrs Nathalie Golovine, who was the wife of a former BIS President, the late Mr Michael Golovine MBE, died on August 2, 1987 and has bequeathed to the Society a cash legacy of £1,500. A bequest to the Society from the Estate of the late James Eric Hall is expected to amount to a comparable amount.

The importance of such donations to the future development of the Society is well illustrated by these bequests, both of which, on receipt, will be allotted to the Building Extension Fund.

The on-going nature of the Society's development and continuing opportunities for new projects underlines the value of bequests to the Society in the years ahead. Members are urged to consider donating to the Society from their Estates and to formalise the arrangement by a Codicil or Will. A Society leaflet, 'Note on Wills and Legacies' is available on request to provide guidance on procedure.

Since the launch of the Building Extension Appeal in May 1987, the total sum received now amounts to £1736.

Space Courses For Teachers

We hear from BIS Member Tom Becker that he will be presenting courses for teachers on 'Soviets in Space' and 'Studying Earth from Space' at Webster University, St. Louis, USA, this autumn.

He writes: "After a long struggle I finally was able to convince a university to offer these courses. Hopefully, this is a major breakthrough for space technology in the St. Louis area and an encouragement for other regional universities to do the same."

New Members For 1988

Applications for first-time Membership in 1988 may now be sent to the Society using the form on the inside back cover of this issue. Early application is advised to ensure the prompt receipt of early 1988 issues of *Spaceflight*.

Existing members, who have the opportunity to bring the work of the Society to the attention of colleagues and others, are particularly asked to introduce new members at this time so they can be admitted by January 1, 1988.

Membership Renewal for 1988

Members should note that the practice of previous years whereby they receive their Annual Renewal Form as an enclosure with the November issue of *Spaceflight* has been discontinued.

Within the next few weeks, members will receive this Form as a separately mailed item and are urged to see that it receives their immediate attention and is promptly returned to the Society. In this way, members can help the Society's administration and ensure that they continue to receive their copies of ***Spaceflight*** and ***JBIS*** without interruption.

JBIS

The November 1987 issue of the Journal of the British Interplanetary Society is now available and contains the following papers:

* * *

Communications and Manned Space Flight – the Vital Link.

Earth Observation from the Space Station

The Space Test Programme – An Update

Enhancing the Quality of Space Education

Soviet Launch Vehicle Failures

* * *

Copies of this JBIS, price £7.50 ($12.00) to non-members, £2.00 ($4.00) to members, post free, can be obtained from the address below. For details of back issues and annual subscription please send SAE to:

The British Interplanetary Society,
27/29 South Lambeth Road,
London SW8 1SZ,
England.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

4 November 1987, 7-9 pm — **Lecture**

FUTURE OPPORTUNITIES FOR EXPLORING MARS

Gary Hunt

Members only. Please apply for ticket, enclosing SAE, in good time.

21 November 1987, 10.30 am — **Visit**

UNIVERSITY OF SURREY

A tour of the UoSAT Spacecraft Engineering Unit for school teachers who attended SPACE '87 and would like more detailed information about the University's work. Further details from: Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose SAE.

2 December 1987, 7-9 pm — **Lecture**

REMINISCENCES OF BLUE STREAK

C.H. Martin

Members only. Please apply for tickets, enclosing SAE, in good time.

3 February 1988, 7-9 pm — **Lecture**

ENCOUNTER WITH HALLEY'S COMET

Prof. J.A.M. McDonnell

Members only. Please apply for ticket, enclosing SAE, in good time.

5 March, 1988, 10.30 am — **Visit**

UNIVERSITY OF SURREY

A tour of the UoSAT Spacecraft Engineering Unit for BIS members. Further details from: Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose SAE. Numbers will be restricted so please apply in good time.

9 March, 1988, 7-9 pm — **Lecture**

HOTOL – A SPACEPLANE FOR EUROPE

G.P. Wilson

Members (plus one guest) only. Please apply for ticket, enclosing SAE, in good time.

23 March, 1988, 10-4.30 — **Symposium**

HISTORY OF BLACK KNIGHT

An all-day Symposium. Refreshments will be provided and as numbers are limited early registration is advised.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

19 April, 1988, 10-4.30 — **Symposium**

DIRECT BROADCAST BY SATELLITE

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

High power direct broadcasting into individual homes could have great potential but, as with any investment in commercial space technology, the risks are high. Each European country is proposing its own national programme but a single satellite could cover all of Europe. Britain struggles to come to a decision on the future of DBS. Would cable or medium power TV satellite distribution be a better answer? A wide range of technical problems will be the subject of this one-day symposium.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

Computer Aided Engineering

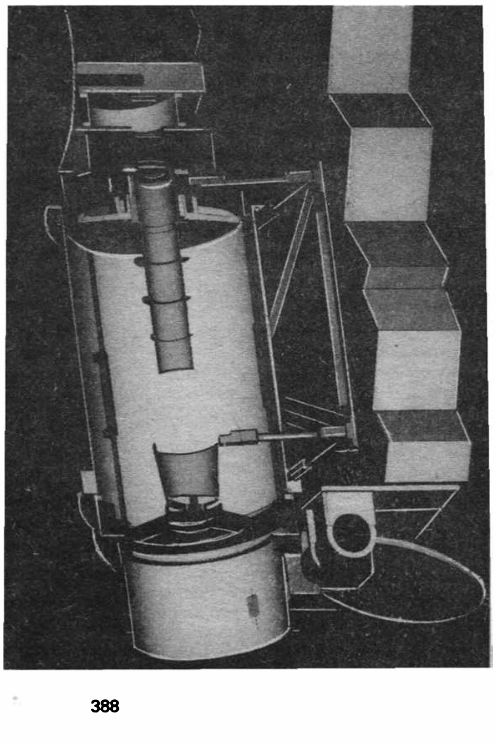
The von Karman auditorium at JPL features a fine collection of spacecraft models: Ranger, Surveyor, early Mariners, Viking, Voyager, Seasat, IRAS, Galileo, and more. Those with solar panels look like giant dragonflies with blue, veined wings – one species with two "wings" flies in the strong sunlight of the inner Solar System to Mercury and Venus while the four-winged variety is definitely Martian. Their wingless brethren, destined to travel far from the Sun, in the outer Solar System, derive their electricity-giving warmth from inner resources. It is educational to see the solutions which have evolved not only for power generation but also for antenna placement, fuel-tank location, and other configuration problems.

Indeed, establishing the configuration of a spacecraft so as to meet launch vehicle constraints, subsystem interface requirements, thermal requirements, attitude control system capabilities and science requirements is a challenging problem that is faced anew by every project. The configuration development process has been markedly improved in quality and efficiency through the introduction of computer-based techniques.

"Computer Aided Engineering" (CAE) is the phrase used by Brian Muirhead, supervisor of the Advanced Spacecraft Development group at JPL, and his colleagues to describe this evolving technology. The particular tools used at JPL were brought to the Laboratory about three years ago: software systems from Applicon and from Structural Dynamics Research Corporation. Totalling well over one million lines of code, these computer programs allow the configuration designer to develop and iterate in rapid fashion a complex spacecraft design. The design, displayed on a high-resolution monitor or output on paper, is produced by performing Boolean operations among a set of solid geometric objects such as spheres, cubes, cylinders, surfaces of revolution, etc. That is, from two objects a third can be created as a result of addition, differencing, or intersection. This type of geometrical representation and manipulation is called solid modeling. In addition, previously created objects can be stored in a library and recalled at will. The JPL designs for CRAF, Cassini and many other projects are now done solely on these computer systems.

An important application of this type of design and analysis system lies in the domain of geometric verification. If a spacecraft is to be launched from the Shuttle, the clearance envelope between the craft with its attached upper stage and the Shuttle bay can easily be determined by doing an "intersection" calculation. A related design question was addressed in sizing and arranging the components of a small spacecraft for lunar exploration, so as to be able to fit the vehicle into a get-away-special canister on-board Shuttle (see the illustration on p.302 of the August issue). The proposed Comet Rendezvous Asteroid Flyby (CRAF) mission plans include firing a penetrator into the nucleus of comet Tempel 2. The CAE software has been used to verify, for various spacecraft designs, that after release the penetrator would safely clear the main structure. The check is easily made by comparing an "object," enclosing all possible trajectories of the penetrator, with neighbouring spacecraft structures via the intersection calculation.

This design for the narrow-angle camera for the Comet Rendezvous Asteroid Flyby (CRAF) spacecraft was produced by means of a computer-aided engineering system now in use at JPL. *NASA/JPL*



A frequent geometrical question addresses possible obstructions of the field-of-view of a remote sensing instrument on-board a spacecraft scan platform. Interference can arise from blockage, in certain directions, by spacecraft structures or from potential specular glints from polished surfaces. By viewing the spacecraft from the boresight of the instrument, and using perspective, potential interferences can be identified and eliminated.

The CAE system is useful for preliminary detailed design of individual spacecraft components such as the camera system. After a preliminary layout and a set of analyses to verify the design (all done within the same computer system) the plans can be delivered to draftsmen for specification of full details. (Incidentally, the time-honoured profession of drafting has also been computer automated, and "blue prints" are now produced without the use of T-square and triangle – we will address this subject in a future issue).

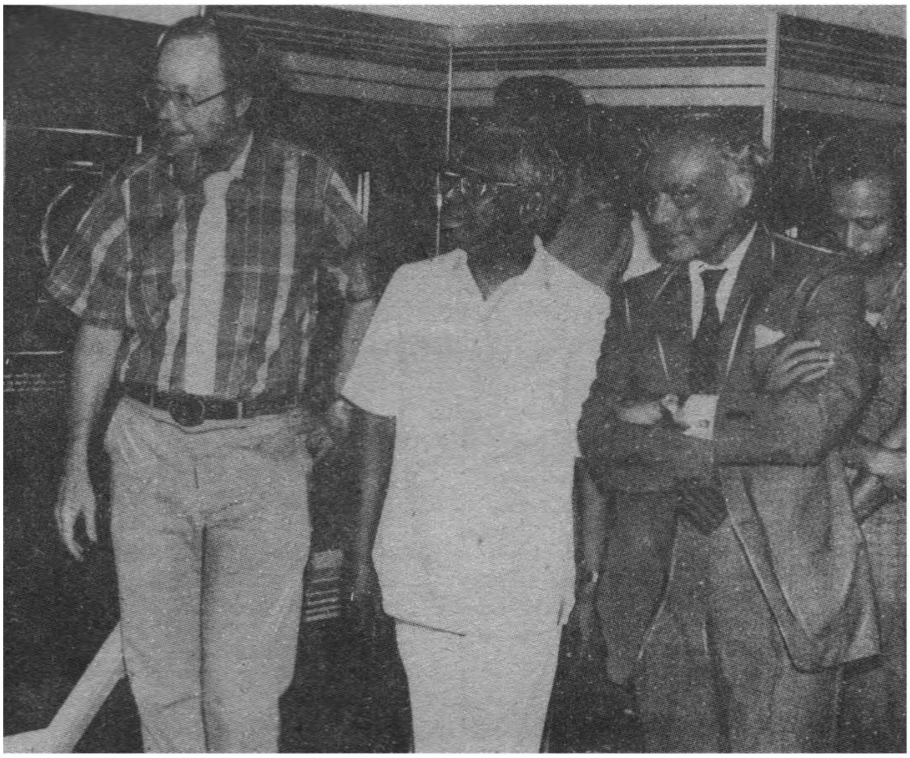
A valuable adjunct to the graphical features of CAE is the ability to compute the centre of mass and moments of inertia of each spacecraft component and system design: a tedious job when done manually. This is the type of problem on which a computer thrives. The only information it needs is the density of each component of the spacecraft. The results are of crucial importance relative to the design of the spacecraft's attitude control system.

Dynamic characteristics of the spacecraft due to the elasticity of its constituent members and materials can be analysed through the method of finite elements; the entire structure is (conceptually) subdivided into small elements each having spring stiffness, in order to emulate elastic behaviour. A special module of the CAE program uses the existing geometry directly to develop the finite element model. It then performs a dynamic analysis and can predict the response of the design to various input forces resulting from launch-vehicle engines, motors on-board the spacecraft, etc. Currently, in this way, the response of a Mars rover design to a simulated crawl on the planetary surface is being evaluated. Another module does large-displacement, nonlinear analysis starting from the basic geometry.

The CAE systems used at JPL put significant design and analysis power directly into the hands of the spacecraft designers. This not only accomplishes the job with less staff, it also produces a more complete and closer-to-optimum design due to the ability to include significant detail and to iterate rapidly. Muirhead observes that the CRAF spacecraft design is far more thoroughly understood than those of Voyager or Galileo at comparable points in time.

Report From India

The exhibition "25 years of Space Photography" has moved from its original site in Pasadena to a series of international showings. This exhibition consists of approximately 100 of the best photographs obtained by JPL spacecraft in the course of exploring the Solar System for NASA: from the early lunar-impact missions of the Rangers to the Voyager explorations of the outer Solar System.



The Honorable Shri K.R. Narayanan (centre), the Indian Minister of State for Science and Technology, and Dr. S. Varadarajan, Chairman of The National Council of Science Museums, are conducted by Dr. William McLaughlin through the exhibition "25 Years of Space Photography" at its opening in New Delhi.

During the period November 1986 to October 1987 the show toured India. I was present at the opening of the photographic exhibition at the Lalit Kala Academy (of fine arts) in New Delhi on July 4, 1987 and contributed some introductory remarks. It was also my pleasure to conduct the Honorable Shri K.R. Narayanan, Minister of State for Science and Technology, through the exhibition.

The impact of the collection of images once again surprised me. With extensive participation in four of the missions, and peripheral involvement in some of the others, my expectation was to experience a visual jog to the memory, precipitating a reminder of past adventures. But the chronologically arranged string of photographs induces something larger than the sum of its parts – an historical perspective. At least two motifs stand out clearly. First, considerable technological progress is displayed from the low-resolution images of the early 1960s to the sharp images obtained by Viking and Voyager. Second, the canonical process of early planetary exploration lies open for inspection: flyby, orbit, landing. For Mars, the three phases have been accomplished (now we will proceed to more detailed inspections including, possibly, the introduction of roving vehicles), while for Jupiter Galileo will implement stage two, and Neptune awaits stage one with the flyby of Voyager 2 in August of 1989.

Following the opening of the exhibition, I gave, over the next two weeks, lectures on "The Exploration of Space" at the national museums in New Delhi, Calcutta, Bangalore, and Bombay. The National Council of Science Museums (NCSM) arranged for the lectures through the Indo-US Subcommission on Education and Culture.

The NCSM represents an intensive effort on the part of the Indian government to increase the level of science education in the country. Dr. Saroj Ghose is the Director General of the NCSM and is stationed in Calcutta, where the original link in the NCSM chain was forged: the Birla Industrial and Technological Museum (1959). The second link, the Visvesvaraya Industrial and Technological Museum, was opened in Bangalore in 1965 and was followed by the Nehru Science Centre (1985) in Bombay. The fourth national-level centre is currently under construction in New Delhi and is scheduled to open in 1990.

The NCSM has devised an effective hierarchical network through the establishment of regional and district centres in the smaller cities. In addition, a fourth level of the hierarchy is represented by a fleet of mobile units which visit the villages of India.

The science museums have emphasised the use of participatory exhibits: an interaction between museum-goer and museum material which extends beyond the merely visual. Thus, children and adults increase their retained information, and their enjoyment is heightened through active relations with the scientific material. For example, the processing of visual information by the brain is addressed by a set of experiments in optical illusions and scene synthesis. An extensive museum-workshop capability allows custom tailoring of the exhibit to the specific needs at hand.

My lecture series in India addressed "The Exploration of Space" and consisted of four parts: (1) astronomical background, (2) the Voyager exploration of the outer planets, (3) the mission and results of the Infrared Astronomical Satellite (IRAS), and (4) future planetary missions. The interest in space is high in India, and it was an invigorating experience to deliver the lectures and answer numerous questions on the space programme and astronomy.

Opportunities arose to visit the very fine planetaria in Calcutta (the second largest in the world, with a 75-foot dome) and Bombay in order to view their shows and talk with their directors. Also, I gained some insight into scientific research in India by visits to the Indian Association for the Cultivation of Science in Calcutta (physics and chemistry, Nobel Laureate C.V. Raman worked here), delivering a lecture on the Voyager project to the staff, and the Indian Institute of Astrophysics in Bangalore. The Director of the latter organisation, Dr. J.C. Bhattacharyya, is a co-discoverer of the rings of Uranus. The Institute produced in its optical shop the 2.3 m mirror for its Vainu Bappu telescope and operates this facility 170 km southeast of Bangalore, at Kavalur.

On a personal note, from the 13 degree north latitude location of Bangalore I was able to see first-magnitude Alpha Centauri (only 4.3 light years distant) for the first time, and the star clouds in Sagittarius were stunning with their brightness in the dark skies of the Indian countryside.

It is most gratifying that India, a country with an ancient culture (the Indus Valley civilisation dates back to the third millennium BC) and a strong tradition in scientific research (Raman, Chandrasekar, Ramanujan, etc.), is looking forward toward the future with such an intelligently thought-out programme in science education.

Imaging Neptune

Upon completion in 1981 of its prime mission to Jupiter and Saturn, Voyager 2 began a long trek through the outer Solar System in order to explore the domains of Uranus and Neptune. (After Saturn, Voyager 1 proceeded on a course that is taking it increasingly far above the plane of the planets, where it continues to return scientific data from this unexplored region). Three major factors have affected Voyager 2's ability to perform in the outer Solar System: (1) low light levels for imaging, (2) long distances from Earth which imply long two-way communication times (over eight hours at Neptune) and, normally, low data rates, and (3) engineering problems accumulated over the ten years since launch.

With regard to these three factors, the Voyager flight team's responses for the Uranus mission were: (1) increasing camera exposure times while, at the same time, holding the camera steady on target to avoid smear, (2) organising for greater efficiency on the ground and programming more autonomy into the spacecraft to mitigate the long communication time; arraying of ground antennas and on-board data compression to compensate for long communication distances, and (3) fixing problems such as a malfunctioning gear train. See the November 1985 (p.403) and March 1986 (p.122) issues of ***Spaceflight*** for summaries.

Science writer Joel Davis has captured the substance of the Uranus encounter in his recent book *Flyby: The Interplanetary Odyssey of Voyager 2.* The author spent many months with the Uranus flight team and has crafted an accurate account. Joel, do I really look *that* much like Solzhenitsyn?

For the Neptune encounter in August of 1989, the flight team has been building upon the improvements instituted for Uranus and adding new capabilities. We looked at some of their activities in the November 1986 and March 1987 editions of this column and return this month to examine some of the scientific and engineering preparations associated with the upcoming imaging of Neptune, its rings, and its satellites.

The Neptunian system, like the Uranian one prior to January 1986, is largely an unknown entity. Discovered in 1846 by J.G. Galle at the Berlin Observatory from calculations by the Frenchman Urbain Leverrier (and, in effect, by the Englishman J.C. Adams), based upon previously unexplained perturbations in the orbit of Uranus, the planet – 30 times more distant from the Sun than is Earth – has been difficult to glimpse. Some of the best Earth-based images were taken in May of 1983 and show bright, cloud-like features (see ***Spaceflight***, November 1984, p. 402). A recently released image of Neptune (see *Sky and Telescope,* September 1987, p. 235) shows new cloud features, raising hopes that its atmosphere may prove more visually exciting than the bland blanket of Uranus.

The manager of Voyager's Flight Engineering Office for the Neptune mission is Dr. Lanny J. Miller. He said that three classes of change were being pursued related to imaging. The first is a new capability, nodding image motion compensation (NIMC), which will be employed to "lock" the camera onto the target as the spacecraft speeds along its path, thus preventing smeared images with their consequent loss of resolution. The second class also reduces smear by improving the "steadiness" of Voyager 2 as an observing platform, continuing work begun for the Uranus encounter. Since light levels will be down by a factor of two at Neptune compared to Uranus, camera exposure times will be commensurately longer, and smear due to random spacecraft motions would be a problem at Neptune if not compensated for. The third class of changes contains modifications to the flight and ground software that permit generation of command sequences with long camera exposure times.

"Just about everything done by Voyager is classic".

Let us briefly examine, in turn, the status of work in each of these three classes.

Miller explained that the purpose of the NIMC effort is to allow image motion compensation to be done, while a picture is being shuttered, without breaking the communication link with Earth. Classical IMC, performed at Uranus, places the spacecraft under gyro control and turns the entire vehicle in a smooth fashion to null out relative apparent motion between the camera boresight and the target: perhaps a satellite (although the camera can be pointed without turning the spacecraft – it is located on a gear-driven scan platform – it is not feasible to use this articulation for image motion compensation). But in the course of a classical IMC manoeuvre, the spacecraft's high-gain antenna is, perforce, pulled off Earth line, and camera data must be placed on the tape recorder for subsequent playback to Earth. The NIMC technique will briefly "nod" the spacecraft off of Earth-line less than two-tenths of a degree, preserving the capability for continuing transport of data to Earth while imaging and not using storage space on the chronically oversubscribed tape recorder. Classical IMC will be used during high-target-rate periods when NIMC is not feasible.

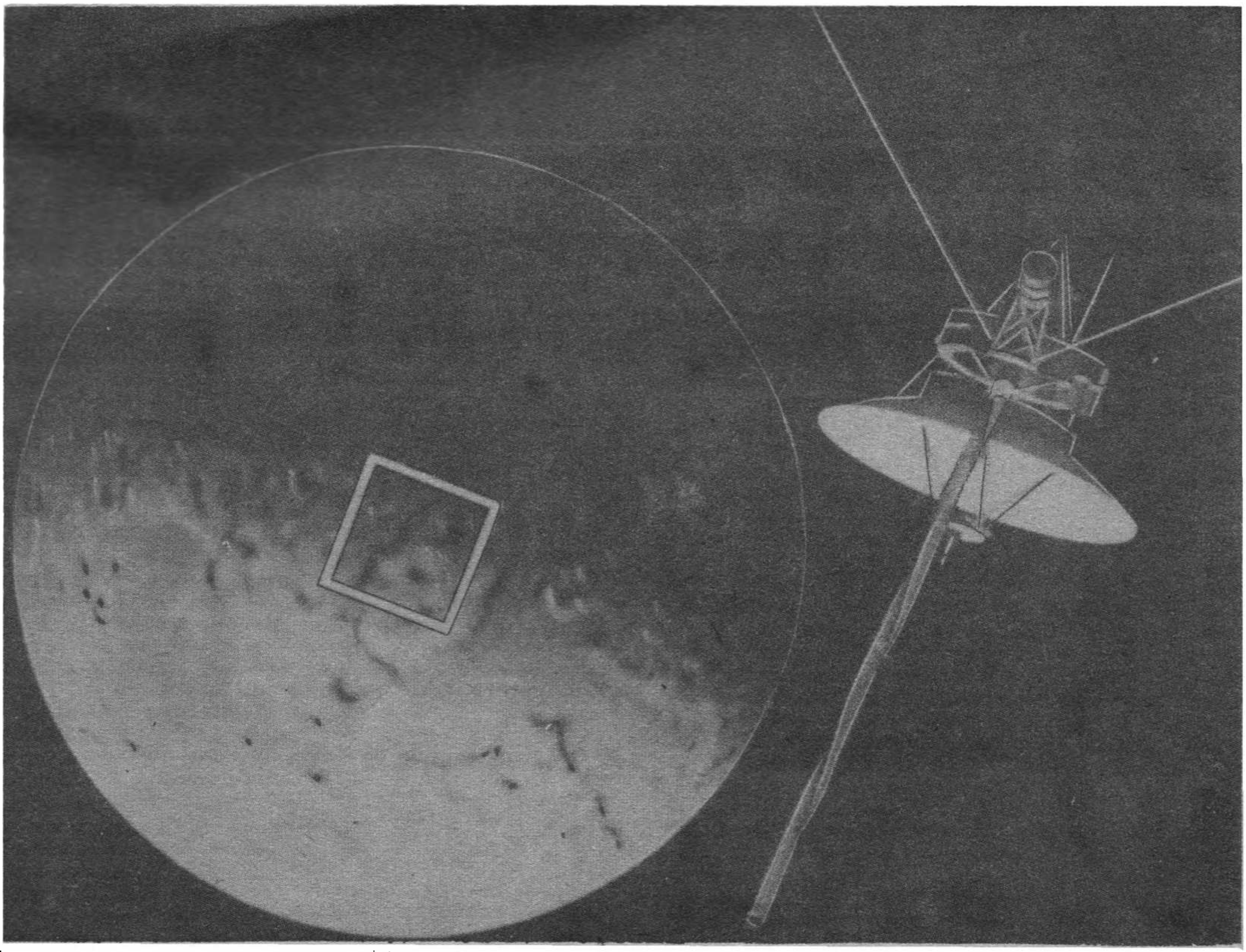
The nodding motion is accomplished by four six-second periods of pulsing of the spacecraft's small attitude-control jets (the same ones that are used to implement classical IMC under gyro control). The first period of pulsing brings the rotational velocity of the spacecraft up to the proper value to null out apparent image motion, then the camera is shuttered for the desired length of time. A second period of pulsing is used to stop the spacecraft turn. Finally, the spacecraft nods back to Earth with two pulsing periods (speed up and slow down). This attitude manoeuvre is repeated for each image: up to 44 times in the current plan. The compensation rate supplied by NIMC changes for each image because the target's angular rate increases as the spacecraft approaches it.

The spacecraft turn rates for NIMC are low. The maximum rate is 175 microradians per second: only one-tenth of the angular rate of the hour hand of a clock! But the manoeuvres are very important for imaging because three or four microradians per second of uncompensated motion will be seen as smear in an image. The 800 kg Voyager spacecraft is being manipulated with a jeweller's precision.

The NIMC capability has been tested with success on-board both spacecraft, but Miller emphasised that further testing could still uncover problems, such as excitation of unwanted oscillations due to the pulsing – this could negate the smear-reduction gains. However, even if NIMC were to be unavailable at Neptune, a not-too-likely outcome, exclusive use of classical IMC would suffice for the highest resolution imaging applications.

The second class of changes, steadying Voyager 2 as an observing platform, is an activity continued from the Uranus mission. Normally, the spacecraft senses its orientation with respect to a celestial reference frame by observing the Sun and a guide star, often Canopus. When these observations indicate that the vehicle has drifted too far (a few tenths of a degree or less) from the desired orientation, in any one of three spacecraft axes, the appropriate attitude control jets fire a burst to move the vehicle back toward the proper orientation. In this way, the spacecraft gently rocks about its equilibrium orientation as it speeds through space. But even these slow, random (not predictable from the ground) rotational motions of a few microradians per second can cause smear in an image.

Electronic activation for valve opening of the attitude control thrusters was done for 10 milliseconds for each burst for the Jupiter and Saturn encounters. Engineers performed careful in-flight surgery on the attitude control sys-



Computer graphic simulation shows Voyager 2 just 30 minutes before closest approach to Neptune's large satellite Triton, on August 25, 1989. Also shown is the size of the footprint of the narrow-angle camera on the satellite's surface. *NASA/JPL*

tem's software for the Uranus encounter and reduced the activation pulse to five milliseconds duration, with proportionate reduction in the spacecraft's rotational rates. For Neptune, electronic pulses will be shortened from five to four milliseconds, which will yield approximately 20 per cent in rate reduction. No further reduction is anticipated because the valves would not remain open long enough to allow effective gas flow. Although Voyager 1 was tested down to four milliseconds prior to Uranus, the capability was not validated for use on Voyager 2 during the encounter.

Occasionally an attitude control thruster will become "impatient" and fire twice rather than the normal single firing employed in controlling the spacecraft's orientation. This phenomenon of double pulsing multiplies spacecraft rotational rates by two when it occurs. Its cause has been identified and the spacecraft's control-law logic has been adjusted to eliminate most double-pulsing events and, hence, further lower the vehicle's average (random) rotational rates.

Third and finally, the flight and ground software supporting Voyager operations is being modified to allow the desired longer exposures to be included in the sequence of commands sent up to the spacecraft. The spacecraft itself will hold its shutter open as commanded, but the software has been "trained" to allow only certain combinations of commands with certain ranges of parametric values.

Voyager software experts, led by system engineer George Masters, have revised the ground software to make it compatible with longer imaging times. In addition, they have been able to compress the imaging cycle for long exposures to permit more of these valuable pictures to be taken during certain phases of the encounter.

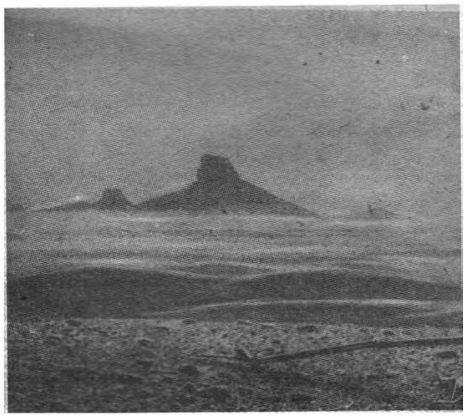
Ken Bollinger, an Assistant Experiment Representative on the Voyager Imaging Team, will be one of the users of the new imaging capabilities for Neptune. He said that typical exposure times during the encounter would be of the order of 15 seconds but that the shutter could remain open for as long as desired. Some images are presently planned for exposures of 840 seconds in searching for indications of faint, diffuse material around Neptune.

A particularly active period for use of the long-exposure capability is planned for 10 to 15 days before closest approach. Diffuse material, ring arcs (in the Neptunian system the rings may only partially encircle the planet; some discontinuous rings were observed at Saturn, and partial rings may have been detected at Uranus), and new satellites will be sought in panoramic views of the planetary system. For example, one imaging pattern will consist of laying down a mosaic of 18 narrow-angle (0.424 degrees) images and two wide-angle (3.2 degrees) shots to cover the system.

Not all imaging activities can be planned with certainty. Since ring arcs or new satellites are problematic, space in the sequence of events will be reserved for their observation, but precise pointing of the cameras cannot be done until the objects are seen in earlier survey images and their orbits calculated.

One of the most spectacular images could result from a plan to capture the shadow of Neptune as it falls on the ring system, just six hours before closest approach. A similar photograph taken by Voyager 1 at Saturn is a classic of space photography. But then just about everything done by Voyager is classic.

Mars Rover Sample Return



Dr. Sally Ride led an effort to recommend future long-range objectives for NASA. Her panel's report, "Leadership and America's Future in Space", identified four possible mission areas: Solar System exploration, human exploration of Mars, an outpost on the Moon, and mission to planet Earth. Two NASA centres, JPL and the Lyndon B. Johnson Space Center, have teamed together to conduct a Mars Rover Sample Return (MRSR) study, thus addressing two of the Ride report's areas. The MRSR would be an unmanned mission but would serve as a precursor to human exploration of Mars.

The basic objective of the MRSR mission is to return to Earth a five-kilogram sample collected from multiple sites on Mars. Dr. Roger Bourke of JPL is Mission Analysis and System Engineering manager for the study, and he described some of the challenges related to this objective, the three most difficult of which would be: a safe landing on Mars, conduct of the rover's traverse on the surface, and the autonomous rendezvous in Mars orbit of the ascent vehicle with the Earth-return vehicle. But first, these challenges will be placed in context by examining the overall mission.

Bourke said that the present focus of the MRSR study is definition of the trade-off space – the domain of design in which mutually dependent mission and spacecraft options reside. Only after the trade-offs are understood can one hope to achieve a sensible point design.

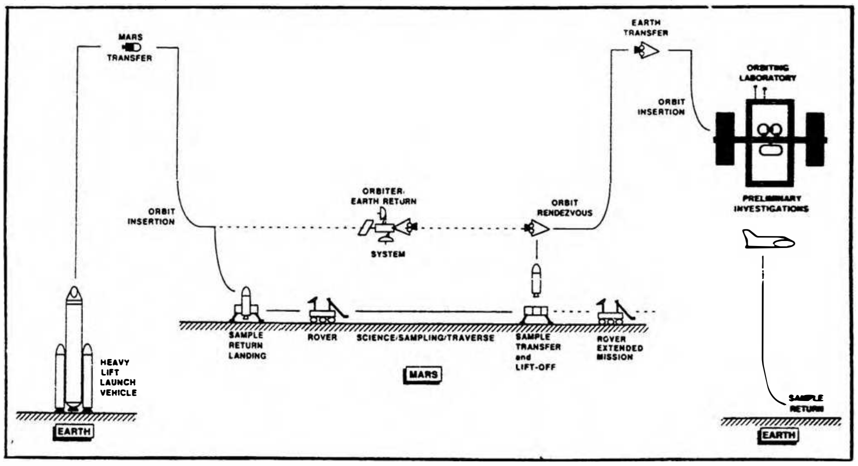
Two principal options are being considered for transport to Mars. The first, labelled "combined launch", would require a heavy lifting vehicle such as the proposed Shuttle C and would send approximately 10,000 kg in one package to Mars. The second, "split flight", envisages flying the rover and ascent vehicle separately to Mars and having them rendezvous on the surface. The first option yields an intrinsically simpler mission but requires more launch-vehicle capability, while the second could employ existing launch systems.

After launch (1998 provides a reasonable opportunity), the cruise to Mars would require nine months, and the spacecraft would be spliced into an orbit about the planet with the help of aerocapture: use of the Martian atmosphere to remove energy from the interplanetary trajectory. Aerocapture would reduce the requirement for chemical propulsion and result in a significant saving in the launch-mass of the system.

The descent from Mars orbit would place a rover on the surface which would gather samples for approximately 500 days of operations. The rover would traverse hundreds of kilometers in exploring diverse and distinct geological provinces, carefully selecting samples for its collection. Rover operation is planned to be accomplished by judicious balance between autonomous decisions by the machine and guidance from Earth.

Upon completion of surface operations, the samples would be placed into the ascent vehicle and delivered to Mars orbit and, after rendezvous, to the waiting orbiter for the nine-months flight to Earth. Arrival in 2001, for a 1998 launch, may occur at a Space Station laboratory which would provide the necessary safeguards to assure that if there were any potentially harmful materials in the Martian sample, they would not be released during the trip to a laboratory on the surface.

A possible mission plan for a Mars Rover Sample Return mission, now under study. *NASA*



Let us now return to the principal MRSR challenges – safe descent, rover traverse, and orbital rendezvous – for a brief review of problems and potential solutions.

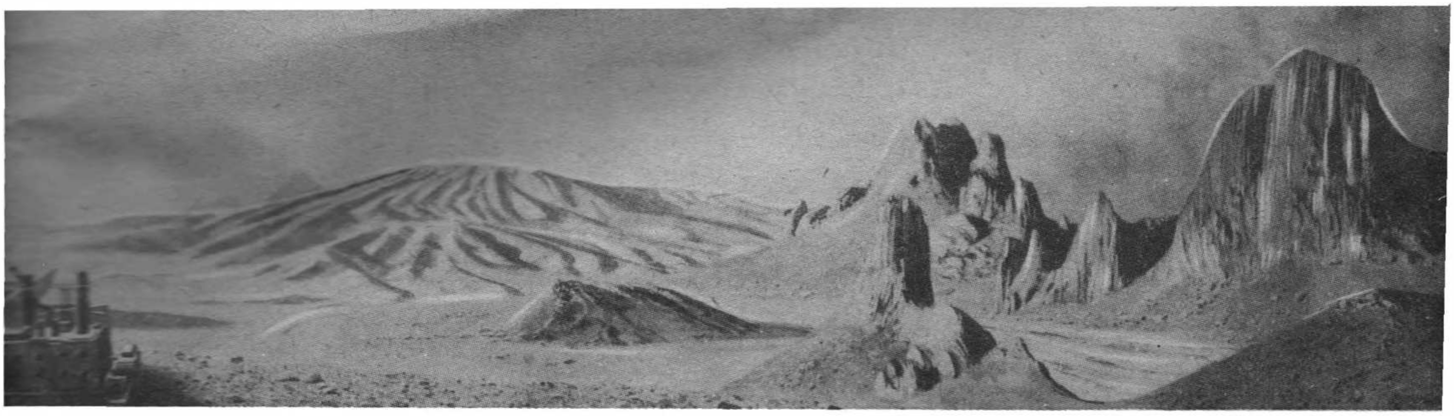
Two Viking landers were successfully placed on the Martian surface in 1976. However, the experience revealed significant possibilities for encounter with hazards. Bourke said that the dual approaches of "brains and brawn" were being entertained in response to the need of hazard avoidance and/or accommodation.

Information gathered by previous missions, including the Mars Observer (scheduled for launch in 1992) and Soviet missions, when combined with observations from the MRSR orbiter would form the basis for landing site selection. The choices made during the descent would be made by on-board systems since long two-way communication times preclude human aid in real-time hazard avoidance.

Several regions of interest on Mars have already been identified, including the Mangala region near the equator and the edge of a polar cap. Of course, the fall-back option of utilising the Viking landing sites for entry points is always available.

The "brawny aspect" of hazard avoidance seeks robustness in the landing vehicle. This virtue might be achieved by attaching inflatable and/or crushable objects onto the landing feet.

Safely on the surface, the 500 to 1500 kg rover must traverse long distances in order to maximise the value of its collection of samples and, at the same time, avoid entrapment by boulders, pits, or other topographic threats. Although help can be furnished by human controllers on Earth, too much reliance on teleoperation, as opposed to autonomous operation, would slow the average rate of progress across the planetary surface. Bourke has instituted the study "A Day in the Life of Mars Rover" to look at the nuts and bolts of this human/machine interface so as to identify problems requiring further analysis. One area of concentration focuses upon management of



A rover on the Martian surface digs and collects a soil sample for analysis. ©Ron Miller

the relatively large amounts of data produced by vision systems associated with either the autonomous or teleoperator modes. The former mode requires significant on-board data processing, the latter implies a capacious data channel between Earth and Mars.

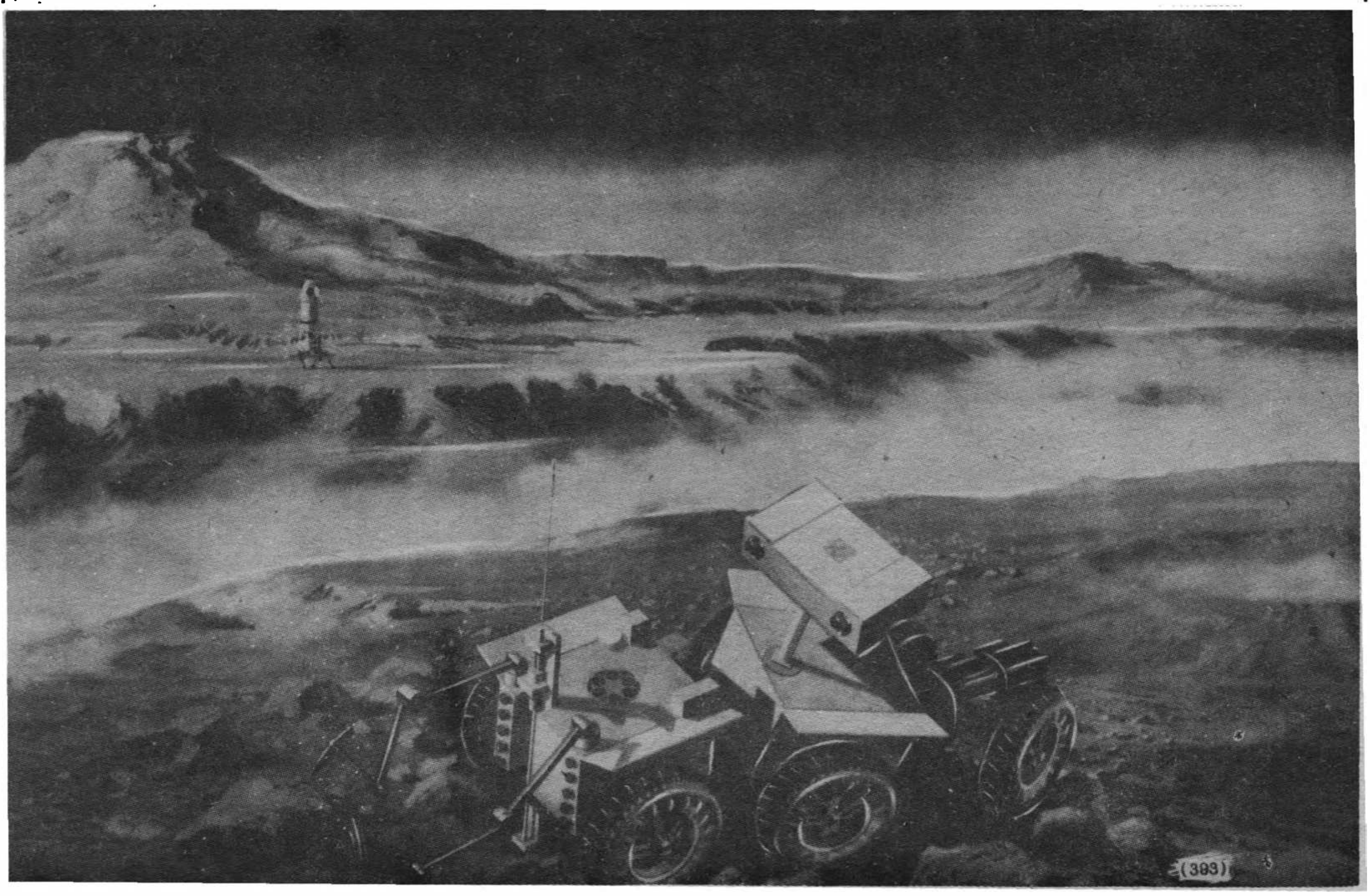
A more detailed insight into rover design options can be obtained from the paper "A Mars Rover for the 1990's" by Brian Wilcox and Dr. Donald Gennery in the October 1987 issue of ***JBIS***.

The third principal challenge for MRSR concerns the rendezvous of the ascent vehicle with the Mars orbiter, prior to return of the sample to Earth. As in the case of rover operations, autonomy can be blended with teleoperation. Here, the penalty for teleoperation is that the slower characteristics of this mode would probably require the ascent vehicle to be longer lived than for autonomous rendezvous. This, in turn, might require solar panels (rather than a battery) for a source of power, a more extensive thermal-control subsystem, and other features which imply additional mass and complexity.

The programme management for the MRSR study is supplied by NASA's Solar System Exploration Division. The study manager is Dr. Donald Rea of JPL, and Jay Greene of the Johnson Space Center (JSC) is the deputy study manager. The split of responsibility in the study is along the lines of system elements with the Texas centre handling the Earth-to-Mars, and return, vehicles; aerocapture; landing; ascent; and sample recovery. The California centre addresses the Mars orbiter and the rover. Roughly speaking, JSC is concentrating on transportation to and from Mars while JPL is looking at planetary surface operations. JPL is prime, with JSC support, for integration, implementation planning, and mission design.

The scientific opportunities inherent in a laboratory examination of Mars samples include the possibility of detecting fossil life, age dating, and mineralogical analysis. As a stand-alone scientific expedition, as a precursor to the human exploration of Mars, or as an instrument for US leadership in space, the Mars Rover Sample Return would be an outstanding mission, if approved. A target date for seeking a project start is fiscal year 1993 (currently, formulation is underway of fiscal year 1989 new-start candidates within the NASA budget).

A rover collects samples on the surface of Mars in this depiction by artist Ken Hodges. In the background is the ascent vehicle and an orbiter (not to scale) flies overhead. A Mars Rover Sample Return mission is now being investigated in a joint study conducted by the Jet Propulsion Laboratory and the Lyndon B. Johnson Space Center. NASA



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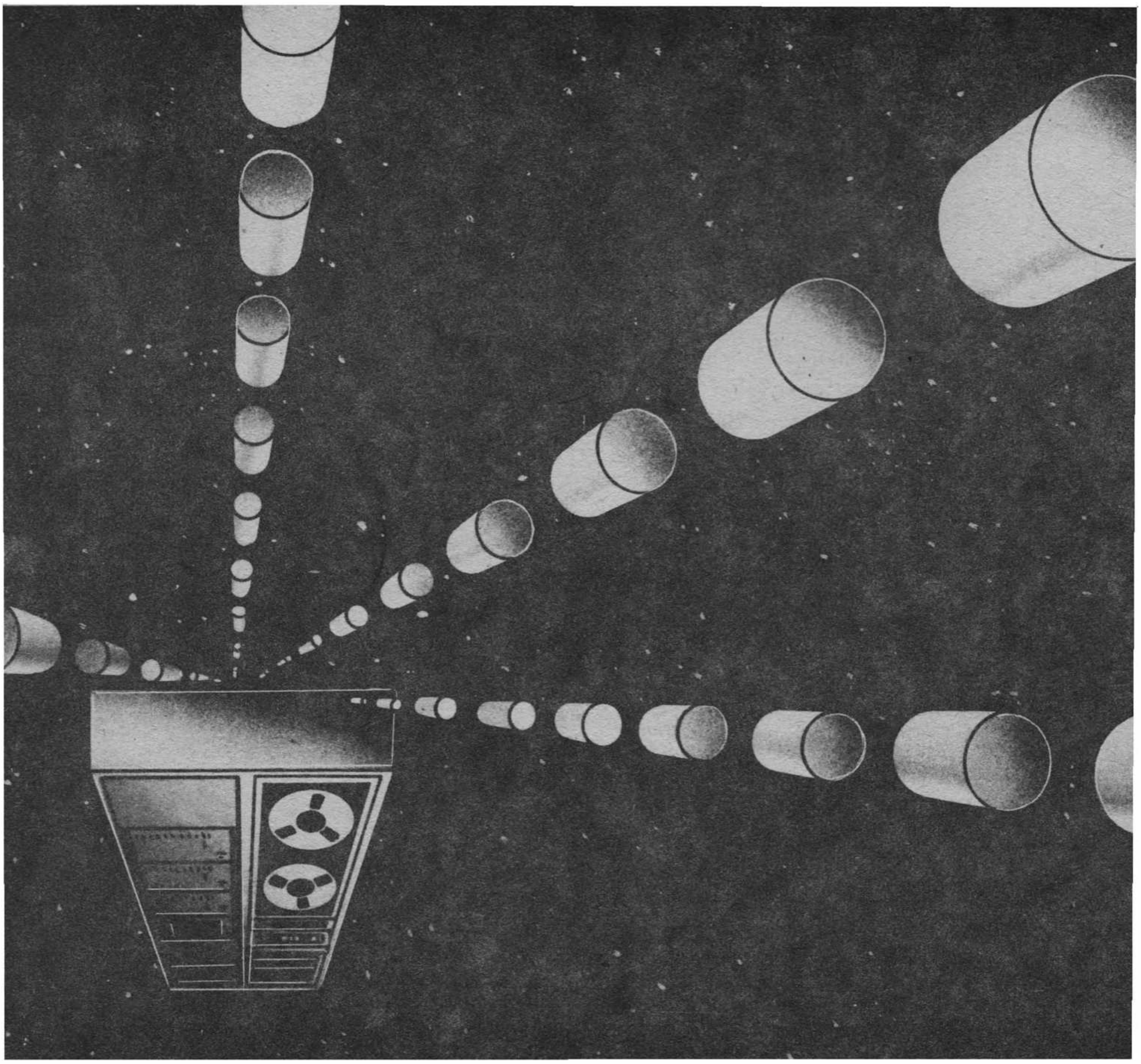
Vol. 29 No. 12

SPACE NEWS and REPORTS



Spaceflight

The International Magazine of Space and Astronautics

Vol. 29 No. 12 December 1987

***Spaceflight* Office:**
27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

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Spaceflight is distributed in the UK and overseas through newsagents by Magnum Distribution Ltd., Cloister Court, 22-26 Farringdon Lane, London EC1R 3AU. Tel: 01-253 3135.

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Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

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Published by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by J.W.L. Ltd., Aylesbury, Buckinghamshire, England.

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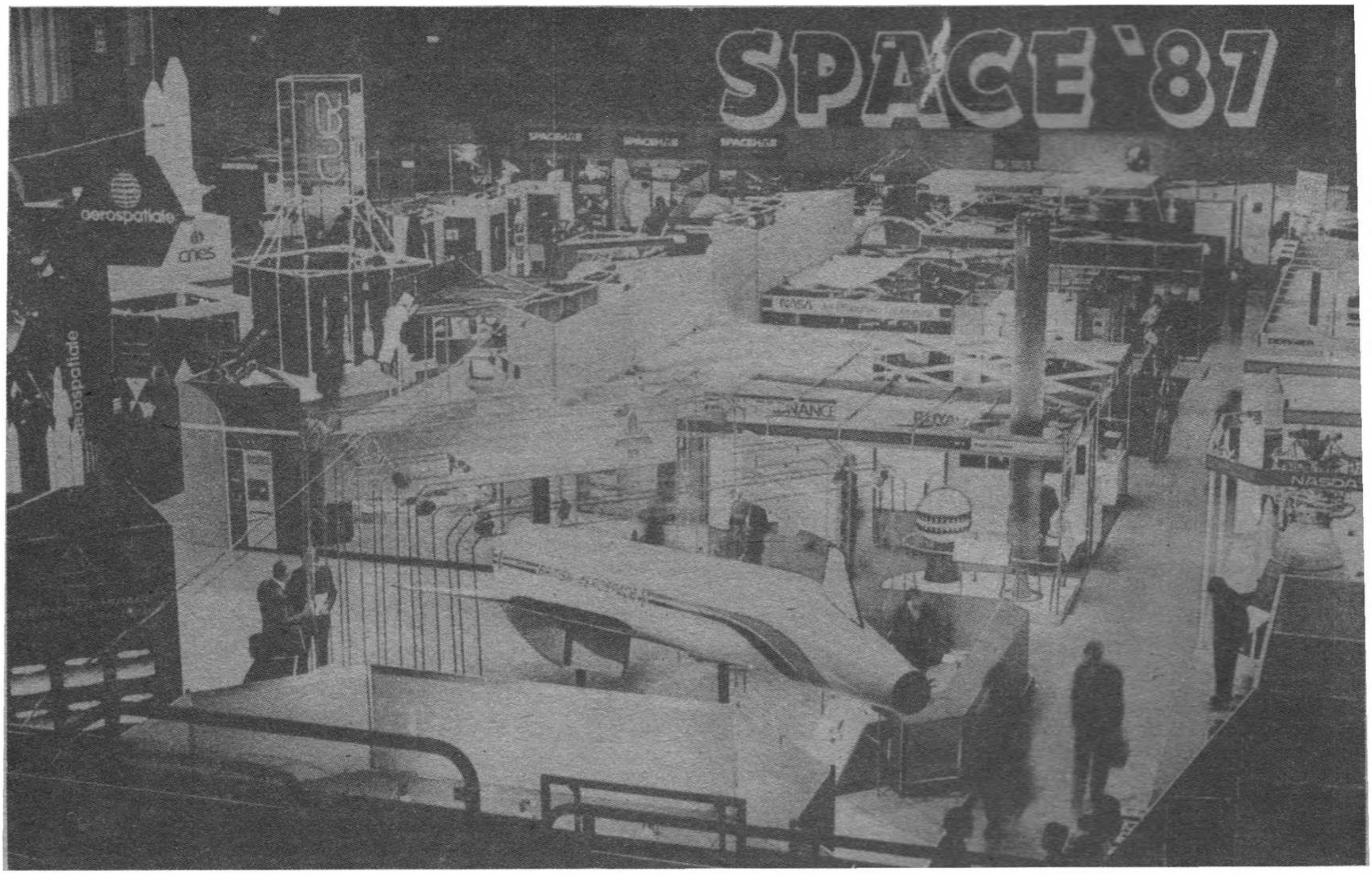
Front Cover: A computer simulation of the EVA to be undertaken when French astronaut Jean-Loup Chretien visits the Mir space station in 1988. The simulation shows the deployment of a 3.8 m diameter unfurlable structure developed by Aerospatiale. The purpose of the experiment is to prove the feasibility of this type of structure for large unfurlable antennas ~~and~~ space station elements in the future (see p. 405).
Aerospatiale



Overview of the main hall of the Brighton Centre and exhibits in SPACE '87. More stands were sited in a hall of the nearby Metropole Hotel. *P.J. Fulford*

Exhibition Puts Spotlight On UK

The UK decision not to increase space funding and a minister's statement labelling the European Space Agency (ESA) as a "hugely expensive club" threw future European cooperation into a state of turmoil at the beginning of October.

Kenneth Clarke, UK minister for Trade and Industry, announced the decision during a television interview on the eve of the country's largest ever space exhibition and the opening of the 38th International Astronautical Federation (IAF) Congress in Brighton.

It left little room for negotiating or compromise at either the government's specially set up committee to review research and development spending, including space, or at the gathering of European ministers for ESA's important meeting in the Hague at the beginning of November.

The decision also seemed harsher, coming as it did on the eve of the opening of the 38th IAF Congress, being hosted in the UK for the first time in 28 years and to which the government declined to send a representative.

During the television news interview, Mr Clarke revealed that Britain was not prepared to spend any more than its current £112 m on space.

Describing ESA as a "hugely expensive club", he said: "We have always stated that the programme put forward by ESA is over-ambitious. They don't really consider the cost of it."

Mr Clarke added that the government had not been persuaded to increase its expenditure based on ESA's present plans.

Some delegates at Brighton from other ESA member nations suggested that the public airing of the UK position a month before the Hague meeting was indicative of a much wider behind-the-scenes debate going on in other countries as well.

At the opening ceremony of the IAF Congress, the largest event of its kind on the annual space calendar, there were messages and speeches from the UN Secretary General and heads of space activities in the US, Europe and USSR. The Congress was formally opened by Sir Raymond Lygo, Chief Executive of British Aerospace.

Some 600 technical papers were presented during the week, in addition to a series of current affairs meetings and numerous formal and informal sessions.

The SPACE '87 exhibition, organised by the British Interplanetary Society which also hosted this year's Congress, was a resounding success with some 70 firms, organisations and agencies from around the world taking part.

As well as being open to Congress delegates, SPACE '87 was attended by a large number of industry representatives and on its final day by more than 1,000 school children, students and teachers.

Exhibitors at SPACE '87 included:

Academy of Sciences of the USSR, Acton High School, Aeritalia Società Aerospaziale Italiana, Aerospatiale DSBS, Air Products Ltd, BAJ Ltd, Boeing Aerospace Company, British Aerospace PLC, British National Space Centre, Butterworth Scientific Ltd, CNES (Centre National D'Etudes Spatiales), Culham Laboratory, Del Mar Avionics and La Calhene (GB) Ltd, Dornier Systems GmbH, Earth Observation Satellite Company (EOSAT), Era Technology Ltd, Eurimage, European Space Agency, Ferranti PLC, Fulmer Research, I.G.G. Component Technology, Interavia Publishing Group, ISC Group Inc., Lockheed Corporation International, Logica Space and Defence Systems, Marcol Computer Systems Ltd, Marconi Electronic Devices Ltd, Marconi Space Systems Ltd, Martin Marietta, SA Matra, MBB-Erno, McDonnell Douglas Astronautics Company, NASA/Jet Propulsion Laboratory, National Aeronautics & Space Administration, National Space Development Agency of Japan (NASDA), Orbit Books/Krieger Publishing Co, Inc., Philips Thermocoax, Pilkington Space Technology, Prospace, Royal Ordnance PLC, Satellites International Ltd, SEP, Singer Link-Miles Ltd, Smith Associates Ltd, Societe Nationale Tour Eiffel, Space/The Shepherd Press Ltd, Spaceflight Magazine, Spacehab Inc., Spur Electron Ltd, SSE Telecom Inc., Surrey Satellite Technology Ltd, Systems Designers Scientific, Teldix GmbH, Thorn EMI Datatech Ltd, Westland Aerospace, Yard Software Systems.

ESA Urged to Trim Plans

John Butcher.

The UK Government has urged Europe to cut back its ambitious space programme. John Butcher, Under Secretary of State for Information Technology, told space industrialists at 'British Day' during SPACE '87 that the UK was concerned with the trend in ESA towards widening development objectives with diminishing regard for commercial realities.

Mr.Butcher was speaking at a special luncheon after touring the SPACE '87 Exhibition in which 30 UK companies took part. His comments came two days after a statement on British television by the Trade and Industry Minister, Mr Kenneth Clark (see previous page).

Mr Butcher claimed that the UK was saying publicly what many other European Governments were saying privately and he went on to say: "We think the time has come for Europe to take stock and to review its space activities against likely future demands of the market.

"Of course we appreciate we cannot subject space projects to usual quarterly profit and loss account procedures. That is why we support programmes with taxpayers' money in order to provide space industries with opportunities to develop products with commercial applications. But a balance has to be struck between the many competing demands for this money".

Mr. Butcher confirmed that the Government had decided not to increase the existing level of UK space expenditure.

"We will be looking at the Hague (the European ministers' meeting – see page 408) for a reappraisal of ESA's strategy. We think ESA's proposals are very expensive and that not all of the present proposals need to be decided now. We believe they should re-think their proposals and see if they can instil a more commercial slant into their operations.

"Accordingly, we attach great importance to the discussions we are having at present with the private sector on how it can make an increased contribution to the formulation and financing of new space development, both in ESA and under our own national support programme".

However, Mr. Butcher did say that the UK Government would look at the possibility of making more money available for the British Aerospace/Rolls Royce Hotol project.

Earlier in the week the designer of the revolutionary engine that would be used in the spaceplane, Mr. Alan Bond, threatened to take his idea abroad if Government support was not forthcoming.

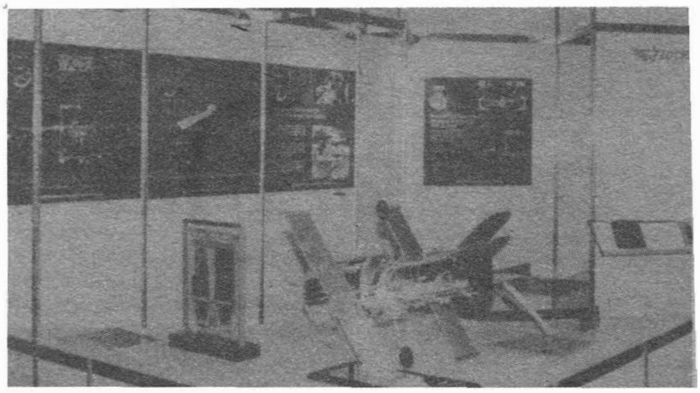
A strong attack on the Government's statement came from the former minister responsible for space, Sir Geoffrey Pattie.

Speaking at the official opening of a new Institute of Space Biomedicine at Sheffield University on October 19, Sir Geoffrey described a "curious fog of myopia" which seemed to have descended over the Government on this issue.

"Can a country which depends utterly on trade and whose trade must depend crucially on developing new products based on materials and processed techniques, afford to opt out of a field which represents the most major concentration of advanced technologies anywhere in the world?" he asked.

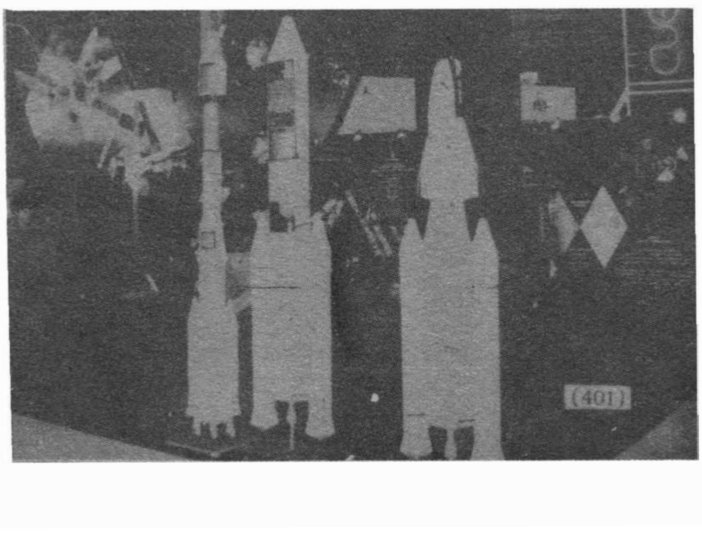
Singer Link-Miles, designers and manufacturers of advanced training systems and simulators.

Model of Space Telescope on the Lockheed stand. *P.J. Fulford*

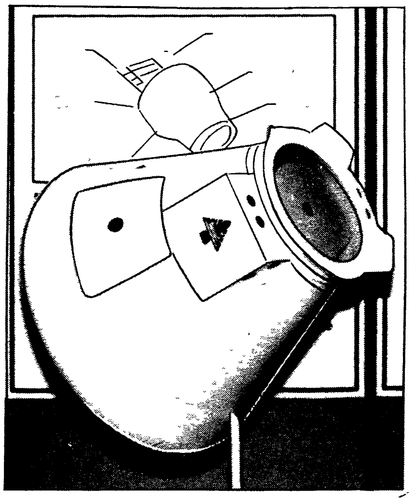


Marconi Space Systems illustrated a broad capability in communications satellites and transponders.

Ariane 4 and 5 models with Hermes on the Aerospatiale stand. *P.J. Fulford*



Multi-role Rescue Capsule



Somewhat eclipsed by the media controversy over Hotol and British space spending during SPACE '87 was the significant announcement by British Aerospace of the multi-role capsule concept.

Capable of being launched by current boosters and the Ariane 4, the capsule (pictured left) would fulfill all Europe's payload recovery and manned transport requirements, also serving as an escape system for the international Space Station, seating six in this mode.

The multi-role capsule is far more than an improvement on the Apollo capsule and is a crucial development for space station operations, according to former Apollo astronaut Buzz Aldrin, who gave his backing to the study.

NASA Gives Out Mars Contracts

Mars rover and sample return mission study contracts have been awarded by NASA to Martin Marietta, FMC Corporation and Lockheed.

Martin Marietta and FMC are to study mobility and surface rendezvous techniques needed for a robotic Martian rover.

Aerobraking techniques that could be used by spacecraft entering the Martian atmosphere are to be examined under contracts awarded to Lockheed and Martin Marietta.

The studies will last for 11 months.

Dornier Wins US Titan Contract

Martin Marietta has awarded a contract to Dornier System GMBH to manufacture the payload carrier assembly for the commercial Titan launch vehicle.

Under the initial contract, Dornier will provide five 4 m diameter payload carrier assemblies for use on the commercial Titan, including two single-satellite assemblies, two dual-satellite assemblies and one test unit.

A payload carrier is a device used on top of the commercial Titan vehicle to cradle the spacecraft until it reaches orbit. When two satellites are launched, the carrier keeps them separate from each other as well.

The estimated value of the initial contract, announced during SPACE '87, is approximately \$18m, with four follow-on options that could bring the total contract value to approximately \$45m.

Beginning in 1989, Dornier will deliver the lightweight graphite epoxy payload carriers to Martin Marietta at Cape Canaveral for installation on the launch vehicles. The first flight of the carrier on the commercial Titan is scheduled for 1989.

"The selection of Dornier for this key launch vehicle element further illustrates the new international character of the commercial Titan vehicle," said Richard Brackeen, President of Martin Marietta Commercial Titan.

The Dornier payload carrier assembly, along with the payload fairing being developed by the Swiss firm, Contraves, will provide the commercial Titan vehicle with enhanced payload capability based on the most advanced proven technologies in composite materials.

Martin Marietta, which entered the commercial launch vehicle business in August 1986, has two firm contracts for satellite launches on commercial Titan. The first contract, with Intelsat, is for the launch of two satellites in 1989 and 1990. The second contract is for the 1989 launch of a satellite built by Hughes Communications for the Japan Communications Satellite Company.

Software for Gamma-Ray Observatory

Logica is developing software to analyse data from the giant Gamma Ray Observatory satellite scheduled for launch in 1990 by the US space shuttle.

Logica's software will perform analysis of data from gamma ray bursts collected by Comptel, an imaging instrument which will obtain some of the first true images of the gamma ray sky in a new (low) energy band.

Gamma ray bursts are occasional dramatic surges of energy from a gamma ray source occurring in the space of a few seconds during a period of otherwise steady or undetectable energy emission.

The software will calibrate all of the data collected by Comptel's burst detectors to find any bursts, then examine them in detail.

Gibson Joins Inmarsat

The former Director General of the British National Space Centre (BNSC), Mr Roy Gibson, has joined Inmarsat as Special Adviser to its Director General, Olof Lundberg.

Mr Gibson, a leading figure in European space affairs and the first Director General of the European Space Agency (ESA), announced his resignation from the BNSC in the summer after failing to get government support for a UK space plan (***Spaceflight***, September 1987, p. 316).

"We feel very privileged that Mr Gibson is joining us," said Mr. Lundberg. "His wealth of experience and wide background in space industries and applications, both in Europe and elsewhere, will be of enormous value to Inmarsat as we face the exciting challenges of introducing new services."

Before his appointment to BNSC, Mr Gibson was an independent aerospace consultant to British and international companies and acted as an advisor to the British and other governments in formulating and applying their space policies.

Between 1967 and 1980, he took a leading role in European space activities as deputy head of the European Space Research Organisation's Technical Centre (ESTEC) in Holland, as Director of Finance and Administration at the Organisation's headquaters in Paris and finally as the first Director General of ESA from 1975 until 1980.

Inmarsat, with 51 member countries following the recent joining of the Gulf state of Qatar and Israel, is the international cooperative operating a global system of satellites for maritime, aeronautical and other mobile communications.

Middeck Payloads for Next Shuttle Flight

NASA has announced the secondary payloads which will be flown aboard the US space shuttle Discovery on the first flight following the Challenger accident, at present scheduled for launch in June of 1988, *writes Roelof L. Schuiling.*

Automatic Directional Solidification Furnace: a technology demonstration of directional solidification of magnetic materials, immiscibles and infrared detection materials.

Physical Vapor Transport of Organic Solids: a 3M Corporation research experiment to grow crystalline films on selected substrates of organic solids.

Infrared Communications Flight Experiment: will investigate the feasibility of using diffuse infrared light as a carrier for shuttle crew communications.

Protein Crystal Growth: the weightless environment of space will be utilised to grow protein crystals of a size and quality needed to determine the molecular structure of the proteins. This type of information is essential to understand protein functions, synthesis and for the design of drugs.

Isoelectric Focussing Experiment: will gather data on the extent of electro-osmosis in space.

Handheld Microgravity Experiment: also called the Phase Partitioning Experiment, it will study the physics associated with the separation of two-phase polymer solutions (in this case dextran and polyethylene glycol). These studies may lead to a better understanding of a method used in separating biological cells.

Aggregation of Red Blood Cells: to study the aggregation of red blood cells and blood viscosity under low-gravity conditions.

Mesoscale Lightning Experiment: TV and photographic data will be used to survey the correlation between lightning phenomena and severe weather activity.

Earth-limb Radiance Experiment: will obtain measurements of Earth-limb radiance for various positions of the Sun.

In addition to the above, two space shuttle student involvement experiments will also be flown.

The Titanium Grain Crystal Reorganisation Study: designed by high school student Lloyd Bruce of St. Louis and sponsored by McDonnell Douglas, this experiment will heat titanium metal filaments and observe the effects of weightlessness on the molecular structure.

Crystal Growth Experiment: designed by S. Richard Cavoli of Marlboro, New York and sponsored by the Union College of Schenectady, New York, this experiment will study the control of crystal growth through the use of a semi-permeable membrane. Such crystals have application to the development of image-intensifying screens for use in detecting Gamma rays and X-rays.

Primary payload for this shuttle flight will be the Tracking and Data Relay Satellite.

Spot Data For Canary Islands

An agreement on the reception of Spot images by the Maspalomas reception station in the Canary Islands, Spain, was signed on October 29 by Mr. Gérard Brachet, Chairman and Managing Director of Spot Image, and Mr. Philip Goldsmith, the ESA Director of the Earth Observation and Microgravity Programmes.

Images taken by Spot satellites over Western Africa, from the Ivory Coast and the Niger to Senegal and Mauritania, will be transmitted directly to the Maspalomas station.

The data recorded at Maspalomas will be sent in the first instance to Toulouse for pre-processing at the Centre de Rectification des Images Spatiales (CRIS), set up jointly by the French national space agency CNES and the National Geographical Institute; the data will then be marketed by Spot Image. Later, some processing will be done at the Maspalomas station with responsibility for marketing remaining with Spot Image.

The Maspalomas station, operated by the Instituto Nacional de Tecnicas Aeronauticas (INTA), is part of ESA's Earthnet system. It has been used for several years to receive data from the American Nimbus 7 and Landsat satellites and will be one of the stations that will receive data from ESA's ERS-1 remote sensing satellite due to be launched in 1990.

Spacehab Expects First Flight in 1991

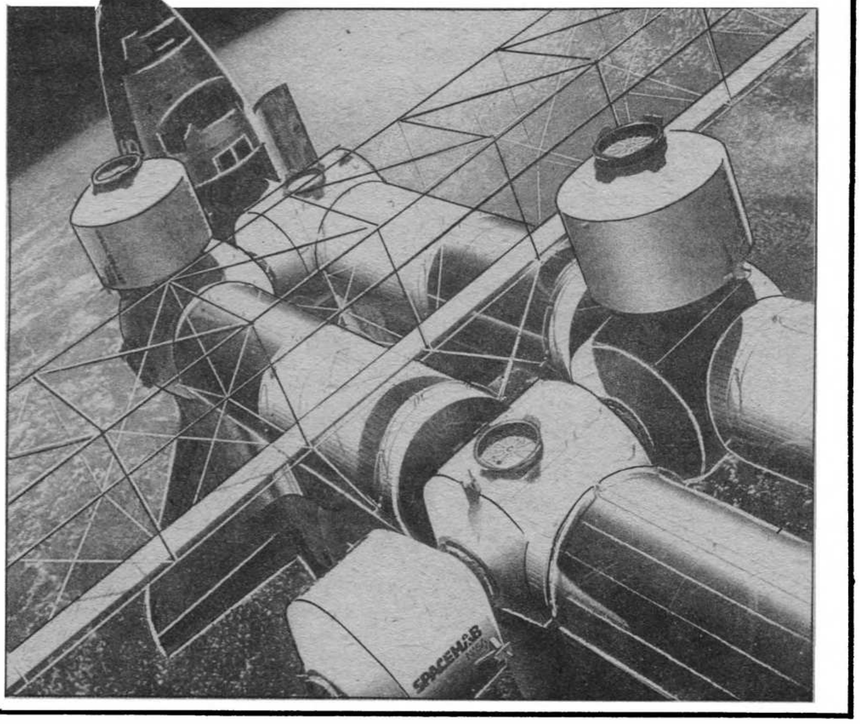
McDonnell Douglas and Aeritalia have completed the Spacehab module Phase-B contract studies for preliminary design and definition it was announced during SPACE '87.

The Phase-B studies validated the feasibility of the concept and resulted in an increase in module accommodation to satisfy customer requirements.

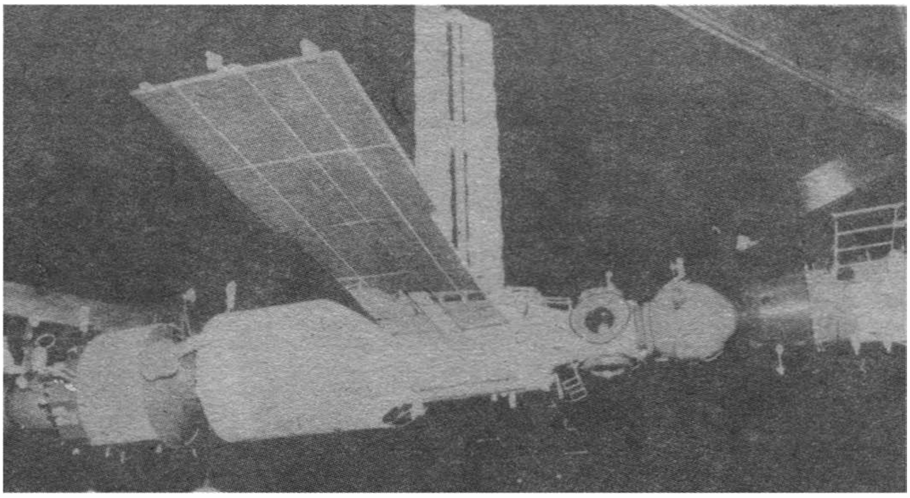
The refined definition of the Spacehab modules added additional capabilities to the modules, including significant increases of power availability for experiments, active cooling and independent environmental control and life support systems. A data management system, which can be accessed by users, is now part of the baseline Spacehab module design.

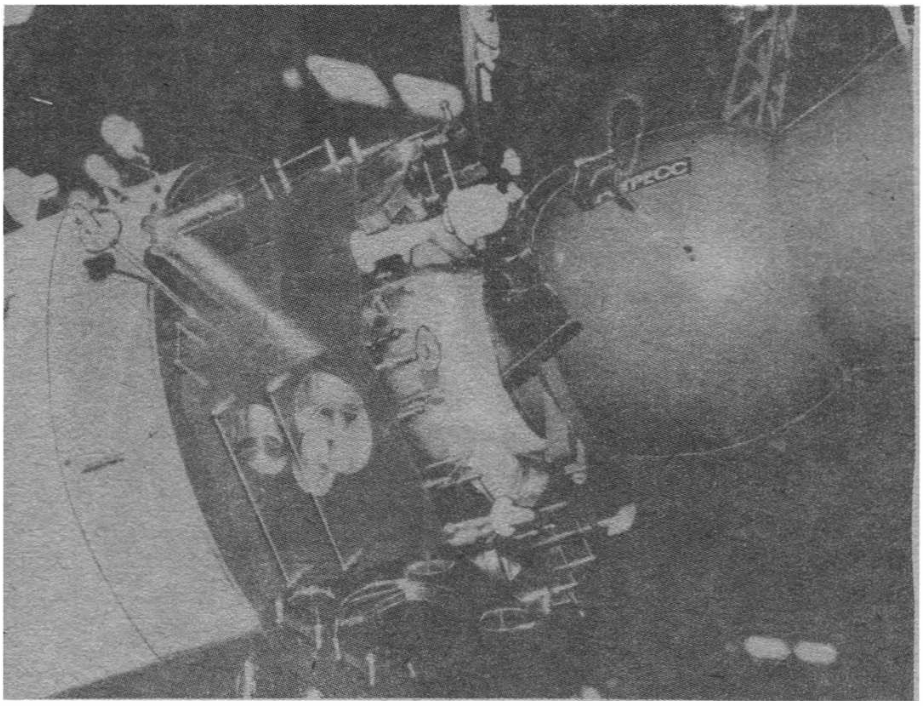
When the extended Phase-B studies are completed next year, Spacehab plans to begin Phases C/D (detailed design and construction) for the modules which wiill take about three years.

Two modules are being built and one test article, and Spacehab is planning a first module flight in 1991 with two flights a year possible in 1992 and 1993.



Artist's impression of the International Space Station in orbit with Spacehab modules attached.





Soviets Promote Proton

The Soviet Academy of Sciences displayed scale models of the Mir complex (which included the third solar array), the Energia and Proton boosters, and Phobos interplanetary craft at SPACE '87.

The cluster arrangement of the strap-on boosters and an attached 'piggy-back' payload could be examined on Energia – the picture below shows a close-up of the core and strap-on booster engine nozzles.

During a press conference the Soviets did not reveal when the next launch of Energia would be. However, in comments about manned activities on the Mir station, it was stated that the launch of the next scientific module is not scheduled before the end of 1988 or the beginning of the following year.

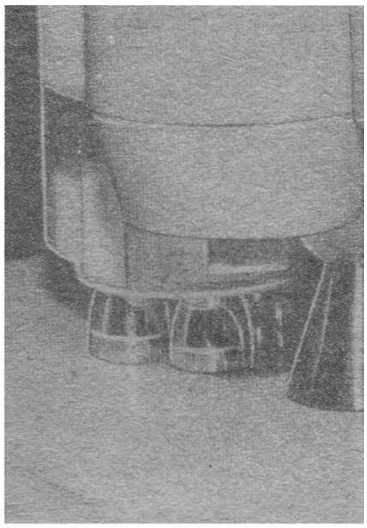
Detailed technical information, in the form of a new booklet for potential customers, was also available on the Proton launcher which is being marketed for the launch of commercial or scientific satellites from other countries.

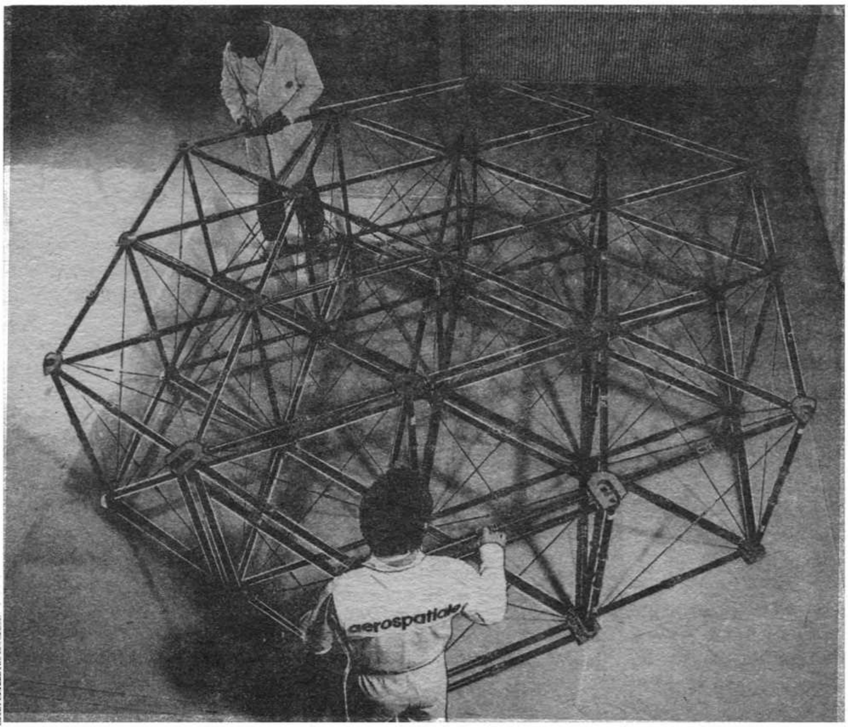
It contains comprehensive notes on launch site and ground facilities operations, payload preparation and integration, as well as safety rules and requirements.

According to the booklet, for example, a customer's satellite and its

Top left: Scale model of the Mir space station complex showing the three solar arrays and *(centre)* a close-up of the Kvant science module with a Progress re-supply vehicle. *Below left:* General view of the Soviet Stand. *Below:* Engine nozzles of Energia's core and strap-on boosters.

P.J. Fulford





French Structure for Mir EVA

Aérospatiale, whose stand formed part of the significant French presence at SPACE '87, is developing a large unfurlable structure to be tested on the next Franco-Soviet flight in 1988.

This structure (left) will be installed on the outside of the space station Mir by French astronaut Jean-Loup Chretien during an extra-vehicular activity. It will then be deployed by remote control from inside the station.

Aérospatiale will deliver three ERA models: a model for training, a qualification model, and the flight model.

The purpose of this experiment is to prove the feasibilty and the concept of this type of structure which will be needed in the future for large unfurlable antennas and space station elements.

equipment can be transported by Aeroflot aircraft only and preparation of the satellite once installed on the launch pad must take no longer than one day.

Information on the launch vehicle, orbital performance, electrical connections and the satellite separation system are all given.

Temperature control for a satellite on the launcher is carried out by an air-conditioning system in the payload fairing.

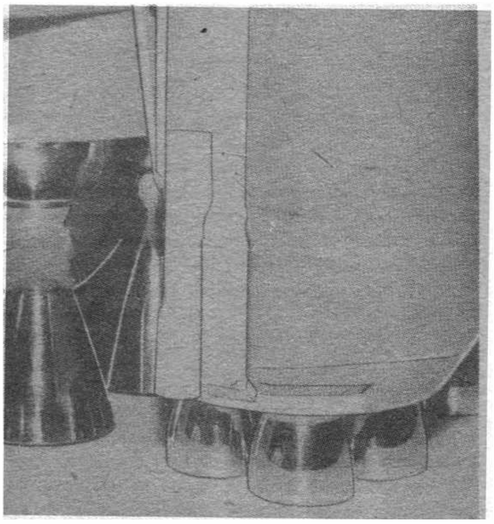
Approximately two hours before lift-off the air-conditioning system is switched off and individual protection devices dismantled. Re-charging of a satellite's chemical battery is stopped 90 minutes prior to launch and service personnel are evacuated as the countdown enters the final hour.

Meanwhile, the USSR has reiterated its assurance over the preservation of technical secrets on foreign satellites launched by a Soviet booster.

Commenting on the United States embargo in this area, Boris Pyadyshev, first deputy head of the Soviet foreign ministry information directorate, said: "We are prepared to guarantee that a customer's interests will not suffer, either in terms of money or from the viewpoint of the preservation of technological or other secrets."

The US companies General Electric and General Motors have already expressed interest and have requested permission from the US administration to have communications satellites launched by Soviet rockets.

China Gets PAM Agreement From US



McDonnell Douglas has signed a technical assistance agreement with China for possible use of the McDonnell Douglas Payload Assist Module (PAM) on the Chinese Long March series of rockets.

The agreement, signed with the China Great Wall Industries Company, will serve as the basis for all future proposals involving the PAM and the Chinese.

The PAM was developed in the mid-1970s to fly either as the third stage of the US Delta rocket or as an upper stage on the space shuttle. It would act as a third stage on the Long March.

"This agreement opens the door for us to proceed with proposals to the Chinese government or with spacecraft customers planning to use the Long March," said Dan Green, Vice President of Marketing and Advanced Program Development.

Green said that if a contract is signed for the use of PAM with the Long March, the Chinese would not be trained to work with McDonnell Douglas hardware. "We would build it, travel with it and do all the preparations ourselves. There would be no transfer of technical information," he said.

Two PAM models have been developed, the PAM-D and PAM-D II. Two more which would be used on the Chinese rocket are under concept definition, the PAM-D III and PAM-D IV.

The PAM, together with the international space station, featured in both displays and video presentations on the McDonnell Douglas stand at SPACE '87.

INTERNATIONAL SPACE REPORT

Engine Leak Poses Threat to June Launch

A leak in the heat exchanger of Space Shuttle main engine number 2027, discovered after the third acceptance test firing on October 10, is being analysed at NASA's National Space Technology Laboratories.

The engine is now mid-way through a tedious six-part leak isolating process. Early mass spectrometer inspections indicate the leak may be in one of the two hardest-to-inspect portions of the oxidizer heat exchanger. Four more distinct test procedures will be used to continue to isolate the leak.

Engine 2027 was the first of three flight engines being acceptance tested for use on the next Shuttle mission, STS-26. Unless it turns out to be a condition common to other engines, the problem is not expected to affect the STS-26 launch scheduled for June 2, 1988.

If the heat exchanger is deemed unacceptable, the present spare engine, number 2028, will be used to make up the three-engine flight complement. This could entail some engine schedule slippage, but ways to minimise delays are being investigated.

Initial data following the 520 second test indicated that the engine performed normally, according to test officials from NASA and the Rocketdyne Division of Rockwell International. During routine post-firing checkout of the engine, however, indications of a potential leak were discovered in the oxidizer heat exchanger. A leak check on the heat exchanger is performed after every engine test firing.

The heat exchanger consists of approximately 28 feet of tubing in the exhaust manifold of the high pressure oxidizer turbopump. A portion of the engine's liquid oxygen supply is routed through the heat exchanger coil to convert the liquid oxygen into gaseous oxygen. The gaseous oxygen is used to pressurise the main oxygen supply in the Shuttle's external tank.

SATELLITE DIGEST – 207

Robert D. Christy

Continued from the November 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1871, 1987-65A, 18259.
Launched: 0400, 1 August 1987 from Tyuratam, by AD-2 or J-1.
Spacecraft data: Not known, although the mass was around 10 tonnes.
Mission: Some form of vehicle test, possibly military photo-reconnaissance, though the payload decayed naturally on 10 August without performing any manoeuvres.
Orbit: Sun synchronous – 173 x 216 km, 88.45 min, 97.04 deg.

PROGRESS 31, 1987-66A, 18283
Launched: 2044*, 3 August 1987 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carring a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Unmanned cargo vessel flying in support of the Mir space laboratory complex. It docked with Kvant's rear port at 1028 on 5 August.
Orbit: Initially 187 x 250 km, 88.81 min, 51.64 deg, then by way of a 256 x 314 km transfer orbit for docking with Mir/Kvant in an orbit of 309 x 360 km, 91.17 min, 51.63 deg.

CHINA 20, 1987-67A, 18306
Launched: 0638, 5 August 1987 from Jiuquan (Shuang Cheng Tse) by CZ-2 (Long March 2).
Spacecraft data: Satellite with a recoverable capsule, length around 5 m and diameter around 2.5 m, and mass around 2 tonnes.
Mission: International micro-gravity experiments payload. The return capsule was recovered in Sichuan Province of China at 0530 on 10 August. The remainder of the craft re-entered on 23 August.
Orbit: 172 x 400 km, 90.24 min, 62.96 deg.

METEOR 2 (16), 1987-68A, 18312.
Launched: 0229, 18 August 1987 from Plesetsk by F-2.
Spacecraft data: A cylinder with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at one end. The length is probably about 5 m, diameter 1.5 m and mass around 200 kg. Stabilisation is by the use of momentum wheels.
Mission: Meteorological and remote sensing satellite.
Orbit: 938 x 962 km, 104.12 min, 82.57 deg.

COSMOS 1872, 1987-69A, 18314.
Launched: 0700, 19 August 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 11 days.
Orbit: 247 x 385 km, 90.88 min, 72.87 deg.

Kiku 5 (ETS 5), 1987-70A, 18316.
Launched: 0915, 27 August 1987 from Tanegashima by three-stage H-1.
Spacecraft data: Three-axis stabilised, box shaped body, 1.4 x 1.67 x 1.74 m with a 9.7 m span solar array. The mass is about 550 kg.
Mission: Technology development satellite including a C-band communications package, and transponders at L-band for use by ships and aircraft.
Orbit: geosynchronous above 150 deg east longitude.

COSMOS 1873, 1987-71A, 18318.
Launched: 0820, 28 August 1987 from Tyuratam, by D-2 or J-1.
Spacecraft data: Not known, although the mass was around 10 tonnes.
Mission: Some form of vehicle test, possibly for military photo-reconnaissance, though the payload decayed naturally on 14 September without performing any manoeuvres (see also Cosmos 1871).
Orbit: 177 x 255 km km, 88.83 min, 64.84 deg.

COSMOS 1874, 1987-72A, 18326.
Launched: 1025, 3 September 1987 by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and

Mixed Fleet Manifest

NASA has issued a new, mixed fleet manifest designating primary payloads for Space Shuttle missions to 1990 and expendable launch vehicles (ELVs) to 1995.

The manifest reflects the high priority assigned to major science payloads. In 1989, five NASA science missions, some with international cooperation, will be launched. Four will fly on the Shuttle.

The four Shuttle missions include Magellan, which will map Venus with a high-resolution radar, in April 1989; Hubble Space Telescope, one of NASA's highest priorities and a cooperative project with the European Space Agency (ESA), in June 1989; ASTRO-1, a Shuttle-borne ultraviolet observatory, also in June; and Galileo, a cooperative project with Germany to make the first comprehensive survey of Jupiter and its moons, in October 1989.

In addition, the Cosmic Background Explorer, a mission to investigate cosmic background noise, is planned for launch on a Delta in February 1989. NASA also will accelerate deployment of other space science missions by full use of ELVs.

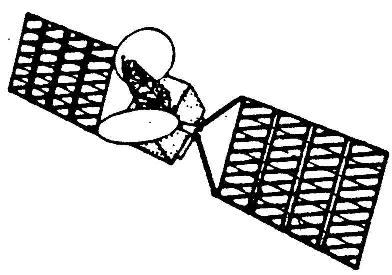
For example, the Roentgen Satellite is planned for launch on a Delta in February 1990 and the Extreme Ultraviolet Explorer is planned for launch on a Delta in August 1991.

In October 1990, the cooperative ESA/NASA Ulysses mission to observe the polar region of the Sun is scheduled to be launched on the Shuttle.

The reformatted launch schedule includes Space Shuttle missions upto STS-44, projected ELV flight assignments, flight histories for the Shuttle and ELVs, and a summary of payload requests for flight assignments.

Secondary payloads, including some commercial activities, will be added to the launch schedules as they are formally assigned.

A manifest for Space Shuttle flights beyond 1990 will be issued following decisions regarding launch vehicle assignments for certain DoD payloads compatible with Shuttle and ELVs.



the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 225 x 291 km, 89.71 min, 72.87 deg.

EKRAN 16, 1987-73A, 18328.
Launched: 1925, 3 September 1987 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with an aerial array in the form of a 6 m x 2 m rectangular panel at one end. Electrical power is provided by a pair of rotatable, boom mounted solar panels at the opposite end of the body, and positioned at right angles to it. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing television and radio services to community aerials in remote areas of the USSR.
Orbit: Geosynchronous above 99 degrees east.

COSMOS 1875-1880, 1987-74A-F, 119334-9.
Launched: 2355, 7 September 1987 from Plesetsk by F-2.
Spacecraft data: Each satellite is may be spheroidal in shape, about 1 m long and 0.6 m diameter, and with mass approx 40 kg.
Mission: Single launch of six satellites to provide tactical, point to point communications for troops or units in the field.
Orbit: 1387 x 1411 km, 113.81 min, 82.58 deg (lowest), 1411 x 1416 km, 114.13 min, 82.58 deg (highest).

Japan Works On Fuel Tanks For H2 Rocket

The first cryogenic fuel tanks for Japan's H2 rocket are being completed by Mitsubishi engineers using an automatic production facility which is claimed to be one of the most advanced in the world.

The facility, at the Mitsubishi Heavy Industries, Nagoya Aircraft Works was commissioned in June 1986 as part of a major national programme to move into the commercial spacecraft launcher market.

Assistance in the development of the facility, which has been designed specifically to optimise production of the H2's cryogenic fuel tanks, was provided by Sciaky of Chicago.

Sciaky, renamed Ferranti Sciaky Inc (FSI) after Ferranti required the whole of Allegheny's shareholding, traces its involvement in specialised aerospace welding to early stages of the US space programme.

Although smaller than the US Shuttle tanks, the H2 cryogenic tanks are made of the same material, Aluminum 2219. This alloy, containing six per cent copper, requires very special welding techniques and tooling when formed into large structures.

Shuttle SRM Passes Crucial Test

Critical O-rings stayed sealed during the most recent test of the US Space Shuttle's re-designed solid rocket motor (SRM) nozzle joint in spite of an intentional flaw.

A Nozzle Joint Environment Simulator 2-B (NJES 2-B) test at Morton Thiokol's Wasatch Operations site in Utah on October 8, showed that the flaw allowed pressure to reach the wiper O-ring closest to the SRM's propellant, but that the O-ring showed no evidence of pressure blow-by, erosion or heat damage.

The major objective of the test was to evaluate performance of the fluorocarbon wiper O-ring. To check performance, a small opening was placed through the polysulfide adhesive that bonds the nozzle insulation to the case insulation. The opening allowed pressure to reach the O-ring.

The test burn lasted six-tenths of a second and pressure was held for 122 seconds. Engineers are continuing to correlate temperature and pressure data with analytical models.

The next test of the flight configuration for the SRM is due during the latter half of this month (December) when development motor 9 (DM-9) is fired.

DM-9 will provide an opportunity to obtain a database on a "pristine" flight configuration of the SRM and will not contain any induced flaws. Shuttle programme officals are considering plans for inducing several flaws in a later test motor to help evaluate the SRM redesign's reliability and safety margin.

The DM-9 test has been rescheduled because of complications encountered in the nozzle fabrication process. Due to those same complications, the SRM flight hardware will probably be delivered to Kennedy Space Center about two weeks later than originally projected.

At present there appears to be sufficient flexibility in the KSC scheduling system to accommodate the change in the pre-launch processing schedule and still meet the June 1988 launch date.

Thatcher Government Opts Out

ESA FORGES AHEAD

State	Ariane 5	Columbus	Hermes
Austria	0.4	–	0.5
Belgium	6.0	5.0	6.4
Denmark	0.5	1.0	0.5
France	45.0	13.8	45.0
Germany	22.0	38.0	30.0
Ireland	0.2	–	–
Italy	15.0	25.0	12-13
Netherlands	2-2.5	1-1.5	1.5-3
Norway	0.4	0.4	–
Spain	3.0	6.0	5.0
Sweden	2.0	–	–
Switzerland	2.0	–	1.5
United Kingdom	–	–	–

Table showing percentage contributions of ESA member states to the Ariane 5, Hermes and Columbus development programmes.

The UK has opted out of Europe's ambitious multi-million dollar space programme after a stormy two-day meeting of ministers from the 13 member countries of the European Space Agency (ESA).

Despite blatant attempts by the UK government to halt ESA's three most costly and ambitious projects – Ariane 5, the Hermes mini-shuttle and the Columbus space station – ministers formally adopted the long range plans in a package totalling some £7 billion. There was little support or sympathy for the lone British stand.

An Ariane 5/Hermes combination will give Europe an independent capability to launch its own astronauts into orbit by the year 2000, probably to the Columbus space station, Europe's element of the US-led international manned space station.

Britain was the only nation, large or small, not to support any of the three major optional ESA programmes. Progress on development of the Hermes and Columbus projects will be reviewed after three years.

The $3.5 billion Ariane 5 project for a heavy-lift launcher, a follow-on to the already hugely successful Ariane launcher programme which will see the first Ariane 4 launch next year, won strong support with only Britain opting out.

France will take 45 per cent, Germany 22 per cent, Italy 15 per cent with the remainder split among the Netherlands, Norway, Spain, Sweden, Switzerland, Austria, Belgium, Denmark and Ireland, the latter pledging to commit 0.2 per cent.

Hermes, again led by France which will put up 45 per cent of the cost, attracted the support of nine member nations, including Germany and Italy.

Germany took a lead in the Columbus programme with a 38 per cent contribution to the eventual $3.7 billion estimated cost. Seven other countries will be giving strong support.

There remains a chance that Britain could become involved in Columbus through the polar platform although, under ESA rules for handing out contracts, British companies are unlikely to get the prime contractor role previously hoped for.

The UK government representative, Mr. Kenneth Clarke, Minister for Trade and Industry, had attended the two-day meeting in the Hague on November 9 and 10 believing he would win strong support for a severe trimming of Europe's space plans (see p.401).

However, nothing could have been further from the truth as he proceeded with a lonesome attack on the agency's plans.

Mr Clarke warned ministers to reject plans that "led to nowhere", saying that the money required (which for the UK would have meant a tripling of the space budget to around £300m a year) was more likely to cripple European industry than enhance its competitive potential.

He said Britain did not want to be part of "grand political gestures" which he claimed had more to do with "prestige" than wise spending of taxpayers' money.

After the meeting, in a statement reflecting the Thatcher government's harsh policies on both Europe and public spending, Mr. Clarke, said: "Other members have gone off on what we regard as an expensive frolic at enormous expense to the French and German taxpayer in particular. I see no reason why the UK taxpayer should pay for the same privilege."

Although Mr. Clarke's attack on the Hermes programme was widely expected, it came as a surprise when he spoke out against Ariane 5 which Britain had agreed to back at an ESA ministerial meeting in Rome in July 1985.

He claimed that Ariane 5 had since been modified to carry Hermes, a change which would make it uncompetitive when compared with similar rockets under development in America and Japan.

As well as criticising ESA's optional programmes Mr. Clarke refused to go along with a proposed five per cent increase in spending on compulsory science programmes. Britain's contribution to the ESA science budget currently stands at £14m, so the five per cent would have added a mere £700,000.

Mr. Clarke's French counter-part, M. Alain Madelain, was unconvinced by the British argument that private companies should be putting up development cash for the major new projects.

Prof. Antonio Ruboti, Italy's Research Minister, said he could not understand the UK position that future large-scale space projects should attract significant amounts of private rather than public money.

Roy Gibson, who resigned as the Director-General of the British National Space Centre in the summer after government refusal to accept any increase in the annual space budget, said after hearing the outcome that Britain would now have very little influence within ESA.

Sir Geoffrey Pattie, the former minister responsible for space, who was sacked by Margaret Thatcher after she was returned to power in June, said he was "very disappointed".

He added: "Some of ESA's programmes are very closely targetted and refined. In others it is right to ask questions. The danger is that it is very much an 'all or nothing' approach. There is a danger we will be cut out altogether."

Britain's Space Future

Following the failure of the government to back ESA's future programme, the BIS calls for an urgent reappraisal of policy to provide Britain with an effective long-term plan that will place it at the forefront of space technology and space applications.

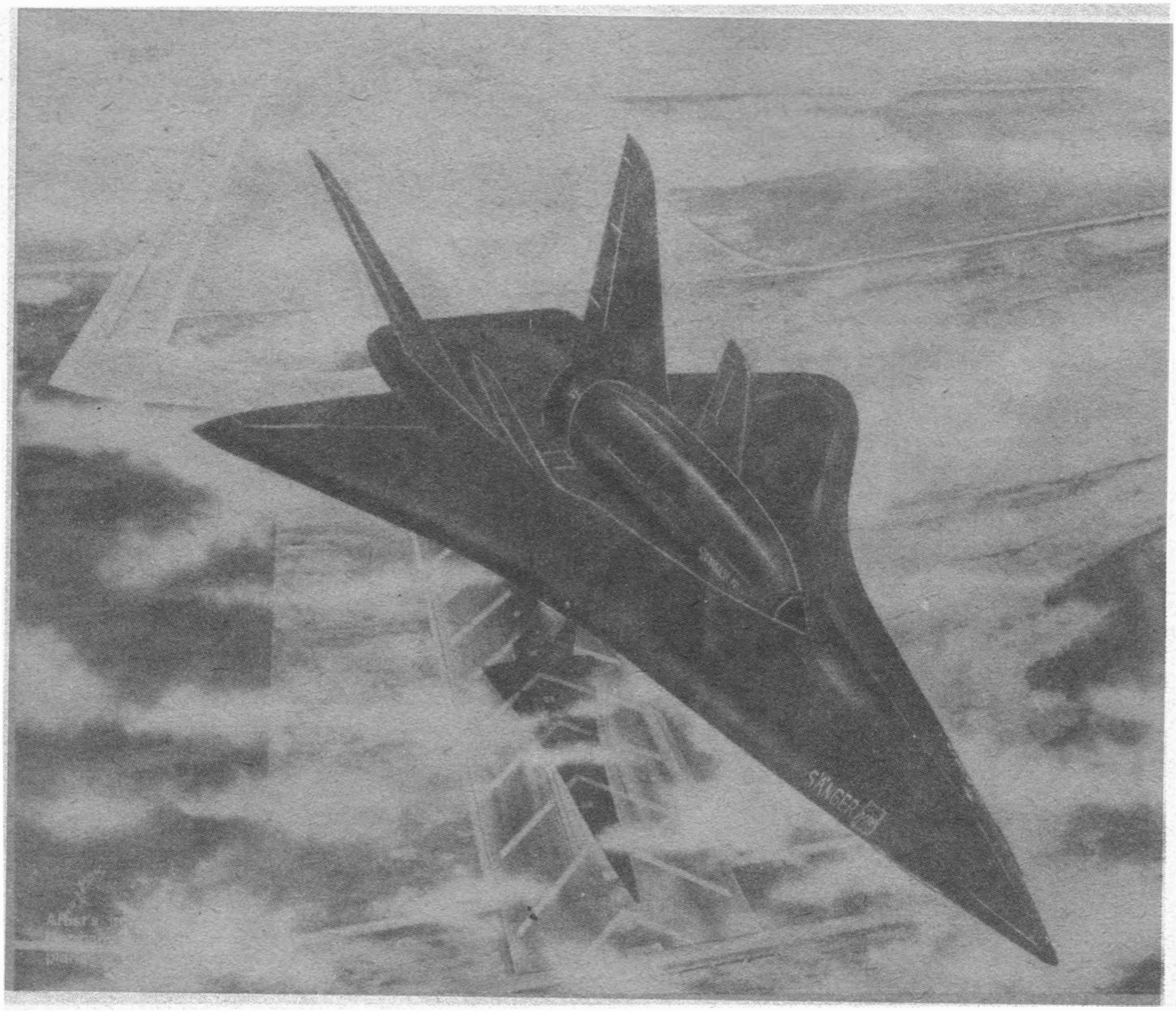
The Society says that the present stance is ill-conceived and will be invalidated by the continuing benefits and influence gained by the increasing number of space-oriented countries in Europe and elsewhere.

Comment

British and European Space Policy

There is a critical level of government commitment and of public funding below which Britain will be unable to remain a serious actor in space, according to the recently published report *British Space Policy and International Collaboration* by Admiral Sir James Eberle and Dr Helen Wallace of the Royal Institute of International Affairs.

Continuation of the present level of British space spending will soon bring the country below that critical level and in this situation Britain would become little more than a user of technologies developed elsewhere and would have little expectation of harnessing space systems to serve distinct British interests.



Spaceplanes - *Key to the Future*

by E. Högenauer

In Europe, the United States and Japan the course is now being set for development of the next two generations of space transportation systems. The decisions to be made will determine not only the future of space travel but of our scientific, economic and political life as well.

The debate preceding these decisions is not of a purely technical nature, since the financial and political aspects of the technology involved will be the decisive factors.

To start, let us try to imagine what the space scenario will be in the year 2000. Firstly, many tonnes of payload will need to be transported into low-Earth and geostationary orbits: satellites, carriers, manned and unmanned space stations and an "orbital transfer" will have been established between the various orbits.

Space-transportation systems currently available in the western world are the products of different levels of technical development:

- Multi-stage launchers of the same classes as the Ariane 4 and Ariane 5.
- Multi-stage launchers with reusable upper stages such as Hermes and space shuttles.
- The single or multiple-stage, completely reusable winged space transporters.

Despite the variety of systems and technologies, a developmental trend is apparent: away from expendable rockets to partially reusable and finally toward entirely reusable launchers.

The full capacity of all available systems is needed to transport the steadily increasing quantity of payload. Payload levels will continue to rise up to the end of the 1990's. For example, the European Space Agency (ESA) estimates a payload volume for the year 1995 of between 50 and 100 tonnes in Europe alone. As a comparison, the Soviet Union currently transports 300 tonnes of payload into space every year.

A projection of European overall transport costs up to the year 2020 indicates that these costs will mushroom:

- £3.6 billion for Ariane 4 launches from 1987 to 1997.
- Between £8 billion and £10 billion for Ariane 5 launches from 1997 to 2005.
- Between £20 billion and £34 billion for all Ariane 5/Hermes launches from 2005 to 2020.

In 1992, for example, the launching costs for all ESA programmes will be

W. Germany Studies Sanger Concept

In West Germany, MBB took up early last year the concept of a reusable manned two-stage space transportation system based on work done by the German space systems pioneer Eugen Sänger in the sixties.

MBB's "Sänger" proposal, which has been submitted to ESA by Germany's Ministry of Research and Technology, presents a future project that could be implemented by the year 2005 to provide Europe with autonomous manned access to space. The essential feature of the project is reusability.

Both the West German Ministry of Research and Technology and ESA have commissioned studies on the Sänger concept and the required propulsion technology. Under contract to ESA, MBB is cooperating with Rolls Royce, MTU and MBW in a study on future air-breathing propulsion systems, and with the Swedish company Saab in a study on flight dynamics during re-entry into the atmosphere. MBB has also been commissioned to perform a study on the overall Sänger concept by the West German Federal Ministry of Research and Technology.

An important Sänger feature is capability to reach any orbit desired after taking off from conventional airports in Europe. The upper stage would be carried "piggy-back" on the lower stage and separate from it at high altitude with both stages able to land at the same airport. Comparable in size to a present-day Boeing 747, the lower stage will be equipped with six air-breathing turboramjets producing 400 kN of thrust each to reach a cruising speed of about Mach 4.5.

The lower stage would climb to an altitude of approximately. 35 km and attain a speed of Mach 7 before releasing the upper stage. The lower stage would then return to its airport base.

The second stage, called Horus (Horizontal Upper Stage) is a further development of the Hermes shuttle, but is also equipped with its own propulsion system and would ascend to an altitude of about 500 km. The two high-performance rocket engines now planned for Sänger's upper stage will deliver 7800 kN of thrust and burn liquid hydrogen and liquid oxygen.

Technology for this high-pressure engine was developed, tested and patented at MBB in the late sixties, and the combustion-chamber technology has for years been used by NASA under license for the main engines of the US space shuttles.

The Horus upper stage is designed to carry from two to six astronauts and a payload of two to four tonnes. Later on, a variant consisting entirely of cabin space for space tourism could carry 36 people for one-day space trips. The unmanned Cargus (Cargo Upper Stage) version could haul 15 tonnes of material into a low-Earth orbit.

Sänger will have a launch mass of approximately 380 tonnes – the first stage will account for about 295 tonnes, of which 150 tonnes will be fuel (liquid hydrogen). Horus is to weigh a total of approximately 91 tonnes, of which 65 tonnes will be fuel and oxidizer (liquid hyrdogen/liquid oxygen). Cargus would weigh a total of 76 tonnes, with 55 tonnes of fuel (LOX/LH) and 15 tonnes of payload.

Sanger ascent trajectories. MBB

From previous page

as high as Germany's present total contribution to ESA funding. The consequences are clear: high launching costs will block the development of new payloads, governmental projects will be cut back and private projects will simply stop.

Space travel will once again be completely dependent upon governmental sources of finance, throwing a logical historical development into reverse.

The initial period of space flight was anything but commercial, being based on military know-how and determined by the political competition for prestige between the two superpowers.

The driving forces behind the gradual development of the European space industry in the sixties and seventies were science and research.

At the beginning of the second period the decision-makers were already endeavouring to achieve a certain degree of commercialisation, and space vehicles are now designed as payload transporters that can be chartered.

The third, future generation of completely resusable space vehicles will be marked by an increasing degree of commercialisation. Paralleling the development of aviation in the thirties, space travel will win a broad customer group by means of its attractive and economical services and, as a consequence, expand rapidly.

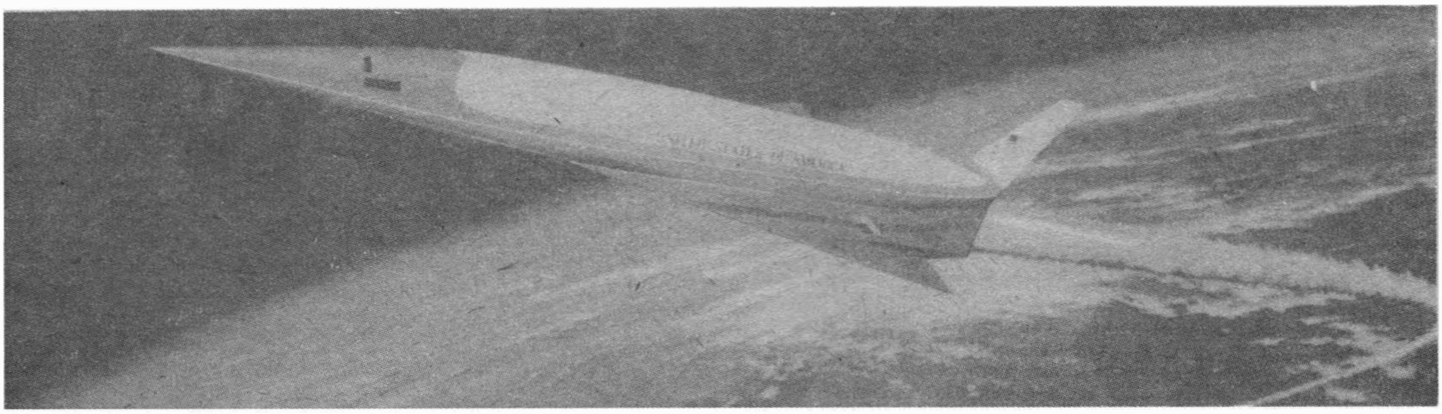
We expect the decisive decrease in costs to come from "reusability" technology. This technology is implemented at least in part by the European shuttle Hermes.

However, the cost-damping effect hoped for will be outweighed in the case of Hermes by three factors:

1. Expendable-rocket technology: complicated and expensive high technology equipment is fabricated, integrated and subjected to comprehensive testing only to be lost after just a single use. According to current estimates, an Ariane 5 launch will cost £73 million.
2. The Ariane and Hermes combination: in this combination the payload capacity of Ariane 5 is reduced from 10 to 4.5 tonnes. Hermes will act as a "dead payload" and increase specific launching costs.
3. Additional infrastructure: the mission of the manned shuttle can only be accomplished if supported by a number of technical systems.

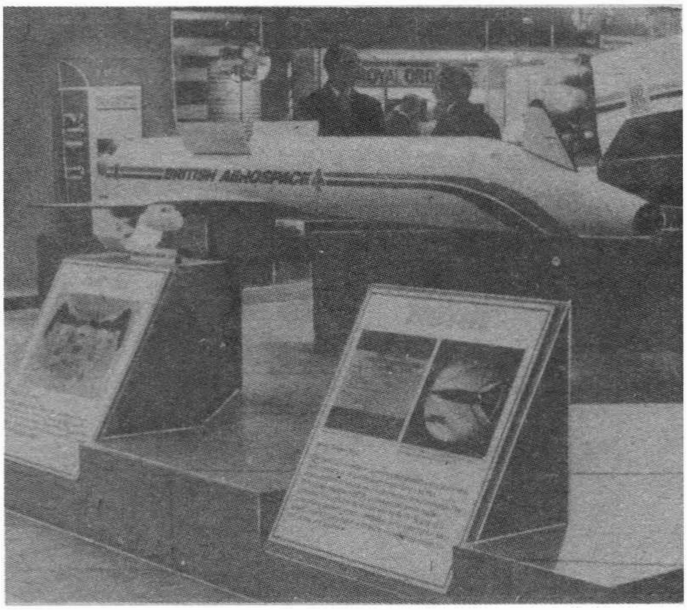
Hermes' task will be to carry men and machines into space for the European space station and then to function as the "umbilicus" to this space station.

However, making the Hermes system work involves not only the development of the space glider itself, but also the establishment of an efficient infrastructure consisting primarily of the following components:



Above: Artist's impression of a future US aerospaceplane being considered under joint NASA/DOD studies. *NASA*

Left: Sir Raymond Lygo, chief executive of British Aerospace, is interviewed by BBC television at SPACE '87 on the future of Hotol. A scale model of Hotol deploying a satellite is pictured below. *P.J. Fulford*



- Integration centre for the space glider.
- Training centre for the crew.
- Control centre for the overall mission with Launch/Landing Control and Orbital Control sections.
- Landing fields.
- Communications system with a data-relay satellite in space and an Earth-girdling network of ground stations.

The Hermes programme will also develop, test and make available to Europe a large number of future technologies:

- Re-entry technology.
- Hybrid flight controls and attitude and orbit control for navigation both within and outside the atmosphere.
- New materials.
- Manned space flight.

Thus, Hermes is a step in the right technical direction, but the operation of the overall launching system is extremely cost-intensive.

The European third-generation transport system which is to supercede Hermes at the beginning of the next century must again leave enough resources available for the development of scientific and commercial payloads, and beyond that, hold its own against the competition in a slowly expanding world market. As a result, the following criteria will be critical to the system's success: Economy, Reliability and Flexibility.

Spaceplane model on the SEP stand.

The aspect of economy has already been examined in detail. Beyond that, only reliable transporters will be accepted by a large customer group. Systems with high rates of failure will be uneconomical in any case.

An advanced space transport system must meet various mission requirements. Customers will not want to pay to send up a manned launcher to position a satellite in a geostationary orbit, for example.

I would like to translate all the requirements placed on the European third-generation space transportation system into the following priority order:

1. The specific payload costs for the transport of men and material into space should amount to at most 20 per cent of the costs for the same mission with Ariane and Hermes.
2. The development costs must be kept to a minimum, which would

mean that proven technologies and those just starting to become available should be used.
3. In terms of reliability and safety, the launcher system must be comparable to airliners.
4. There must be no policy decision to pursue exclusively manned or exclusively unmanned space programmes. The guideline to be applied in planning missions must be "unmanned whenever possible, manned only when necessary".
5. The first-choice launching and landing sites are the largest European airports. The disadvantage of having to start and end missions in the vicinity of the equator should be overcome.

Since space programmes were first begun, many technological and conceptual studies have been performed to achieve the above aims, generally with the emphasis of the investigations being placed on the key component, the engine. Different designs involving single or multiple-stage launchers are conceivable, but all proposed propulsion systems are based on the same concept: in the denser layers of the atmosphere an air-breathing engine is used to accelerate to supersonic speeds, while a rocket engine is employed in the upper atmosphere and beyond to lift the launcher into orbit.

Japan Conducts Basic Research

In Japan a Spaceplane Committee has been set up by the Science and Technology Agency (STA) consisting of researchers in the space, aeronautics and other fields.

It has been considering what type of spaceplane should be made, what the technical problems are and how development of a Japanese spaceplane should be promoted.

Basic research is under way at the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory (NAL) and the National Space Development Agency of Japan (NASDA).

To develop spaceplanes, in addition to research on elemental technology and improvement of testing equipment, demonstration technology will be launched using full-scale experimental vehicles, including ultrasonic manned flight experiment vehicles and unmanned recovery experiment vehicles.

Historical Perspective

In 1942 the space-systems pioneer Eugen Sänger designed a rocket-powered spacecraft that was intended to reach a top speed of 5000 m/s with a payload of one tonne. His concept foresaw a horizontal launch aided by a rocket sled which would accelerate the spacecraft to a speed of 500 m/s. The spacecraft was then intended to climb aerodynamically and attain free flight in space. Prof. Sänger's idea involved the first single-stage reusable space launcher in the history of space technology.

This fundamental work was continued in the USA in the fifties by Walter Dornberger, who designed a two-stage rocket-powered spacecraft. The first stage was propelled by an air-breathing engine and the supersonic glider was designed for speeds from Mach 10 to Mach 15 with a range of 15,000 km. This was followed in the sixties by a series of projects, most of which never got beyond the draft stage, such as a 1964 project by the ERNO and Nord Aviation companies for a two-stage, winged space transporter. The propulsion system for the first stage consisted of a combination of ramjet engines with 72 t of thrust, while the second stage was equipped with four rocket engines providing 35 t of thrust each. With a launch weight of 300 t, the launcher was supposed to put 3 t of payload into a 300 km high orbit. The stages were intended to separate at a speed of Mach 7 at an altitude of 35 km.

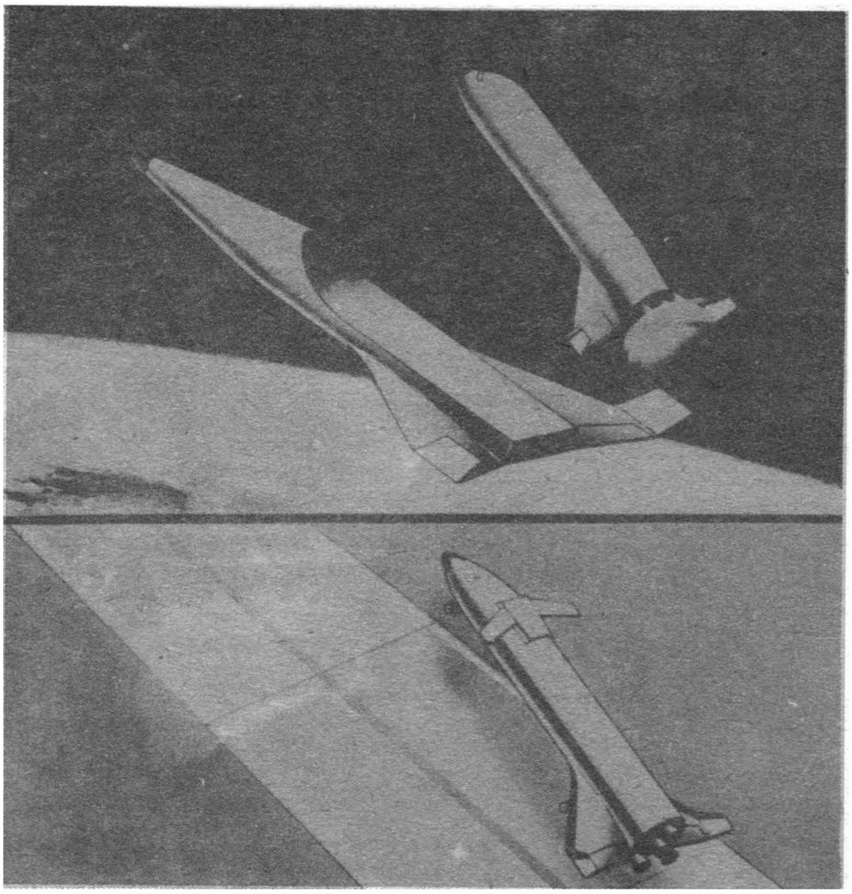
In Germany, too, the mid-sixties saw studies being performed by Junkers, Dornier and ERNO based on Eugen Sänger's concept of reusable launcher systems of two or more stages. One result of this work was a design with a supersonic rocket vehicle as the first stage and a rocket spacecraft as the second to carry the payload into orbit.

None of these projects, however, made it past the optimistic paper stage and the technical knowledge of the forties offered no possibility of realisation. Twenty years later a breakthrough in the development of reusable space transporters seemed close at hand since broad-based conceptional studies had been conducted in both the United States and Europe, but then the Saturn/Apollo programme channeled all efforts into the development of improved multiple-stage expendable rockets. Now, another 20 years later, the technological, financial and political prerequisites have been fulfilled and the time finally seems ripe to make reusable spacecraft.

The United States and Great Britain have, for some time been developing and have now presented new concepts for the future generation of space transporters.

The concepts of both countries depart from multiple-stage vehicles and propose single-stage systems capable of taking persons and payloads into a low-Earth orbit and consequently of operating, with an engine

Two possibilities under consideration by French firm Aerospatiale are a single stage system (bottom) using rocket propulsion and a two-stage air-breathing/rocket engine. *Aerospatiale*



yet to be designed, at speeds up to Mach 25.

Feasibility studies funded by the respective national space budgets are now being conducted on the NASP (National Aerospace Plane) project of the United States and the Hotol (Horizontal Take-off and Landing) project of Great Britain. Considerable impetus is being lent to the NASP project by the military, or more specifically by DARPA (the Defense Advance Research Project Agency) which is promoting the development of engine technology in particular.

The NASP development work entailing the most effort and expense is in the field of propulsion technology. What is needed is a combination engine covering the wide range of Mach speeds. In the lower speed range up to Mach 5 turbojet or subsonic ramjet engines are required, but above these speeds another kind of engine must be used: either the supersonic combustion ramjet, known in the vernacular as a "scramjet" or a combination of scramjet and scramrocket.

In contrast to ramjets, scramjets do not slow the air to subsonic speed so that it can be used to burn liquid hydrogen, but burn the hydrogen in supersonic streams at lower temperature. This dramatically increases engine efficiency. Although in principle it sounds simple, the problems involved in actual practice are just the opposite.

So far, the UK has achieved the most significant publicity in presenting Hotol.

Like the Aerospaceplane, Hotol is a single-stage, completely reusable transporter that is to take off from and land on airport runways. At launch the spacecraft is positioned on top of a trolley that accelerates the craft to its launch speed of 500 kph before releasing it. Plans foresee both a manned and an unmanned version of the transporter with a payload capacity of seven tonnes (see ***Spaceflight***, April 1986, p.147, January 1987, p.3 and June 1987, p.224).

The magic word in the Hotol project is LACE, which stands for Liquid Air Cycle Engine. In this type of engine, a heat-exchange unit using hydrogen as a medium is intended to cool the intake air to such an extent that its volume is drastically reduced. The cooled air is then pumped into the rocket combustion chamber where it oxidizes the hydrogen in the combustion process.

The transporter carries liquid oxygen on board for the takeoff and trans-atmospheric phase of flight. When the spacecraft has reached a speed of Mach 5 to Mach 7 and an altitude of 26 to 32 km, this oxygen is replaced by air. As a result of the savings in weight provided by this substitution, the extremely lightweight engineering and the aerodynamic optimisation of supersonic flight, engineers expect to achieve a payload ratio of 3.5 per cent, that is to say, seven tonnes of payload with a take-off weight of 200 tonnes.

Company Outlines Low Cost Spaceplane Option

by Dan DeLong and Dr. Ernst Stuhlinger

The Teledyne Brown Engineering spaceplane is a concept for an unmanned space launch vehicle that could be built with current technology. Complete reuseability and engine-out capability would allow it to reliably carry several tons to low-Earth orbit and back at low cost.

Introduction

The unmanned vehicle would be air-launched from a modified Boeing 747 and fly a lifting trajectory to orbit using cryogenic propellants. No external drop tanks or separable rocket boosters will be used and the projected payload capacity is 6,300 kg to a space station orbit or 4,000 kg to a low-polar orbit.

Differences between this concept and previously proposed air-launched vehicles include its relatively high gross weight, its lifting trajectory, and its large initial thrust/weight ratio.

The Teledyne spaceplane requires neither technological breakthroughs nor long development efforts. The engines for example, are currently in use on the US Space Shuttle and Centaur vehicles. Most of the structure could be built of aluminum and graphite epoxy, rather than the exotic materials required for other proposed reuseable space launch vehicles.

This vehicle concept is an effort to identify a programme that can be undertaken immediately to provide near-term launch services to low-Earth orbit (LEO). Unlike other similar vehicle concepts, this effort does not identify any technology development items; one of the tenets is that no technology development need be done in order to build the system hardware. All major components and systems are based on currently available aerospace or commercial hardware.

Within this context, all efforts were made to minimise the cost of launching freight to LEO. Other missions and payload services were added only if they did not significantly detract from the business of low-cost freight hauling.

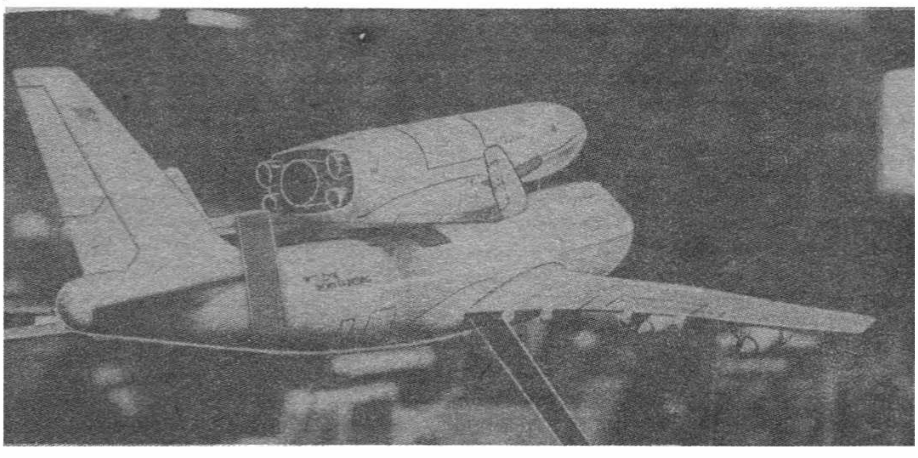
Potential Uses

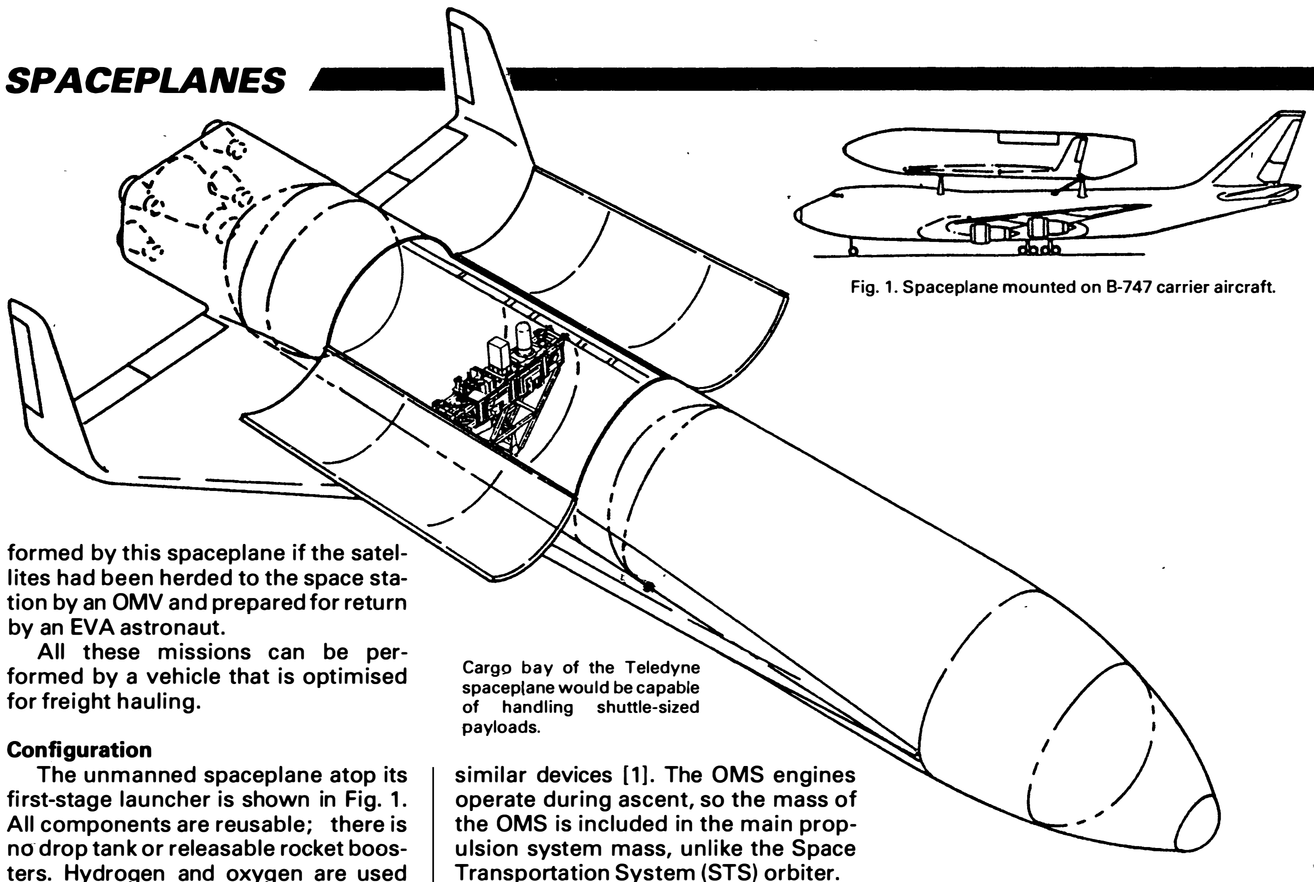
Several uses were indentified for the near-term, first flights. These include launching of selected military payloads, standby for astronaut rescue, space station construction and resupply materials, and propellants for the Orbital Manoeuvring Vehicle (OMV) and perhaps the Orbital Transfer Vehicle (OTV). Materials processing systems, including free-flyers, could also be serviced by this vehicle. These early uses of the spaceplane are all of the type that require little or no flight insurance. Thus, the early flights need not necessarily pay the high insurance premiums that are associated with unproven systems with short track records.

Later uses for the spaceplane include launching of commercial satellites up to the mass of a PAM D-11 system. Space station logistics modules or Spacelab modules could also be carried and transferred to and from the space station. These modules could be manned as design maturity and confidence are gained, or possibly as later, man-rated vehicles are built. Routine up-and-down transportation of space station crews could then be undertaken.

Other later uses include multiple launchings of large spacecraft for assembly at the space station; return of spent upper stages, such as a ground-based OTV, and return of disabled spacecraft. The Palapa and Westar recoveries could have been per-

Scale model of Teledyne spaceplane proposal as exhibited at this year's Paris Air Show.





Cargo bay of the Teledyne spaceplane would be capable of handling shuttle-sized payloads.

Fig. 1. Spaceplane mounted on B-747 carrier aircraft.

formed by this spaceplane if the satellites had been herded to the space station by an OMV and prepared for return by an EVA astronaut.

All these missions can be performed by a vehicle that is optimised for freight hauling.

Configuration

The unmanned spaceplane atop its first-stage launcher is shown in Fig. 1. All components are reusable; there is no drop tank or releasable rocket boosters. Hydrogen and oxygen are used for all propellants, including main propulsion, orbital manoeuvering system (OMS), reaction control system (RCS), fuel cell electric power, and hydraulic power for the aerodynamic surface actuators and for repressurisation of the main tank structure as the vehicle cools down after re-entry. Because all these systems use the same pair of propellants, residuals are kept to the irreducible minimum required by launch performance uncertainties.

The vertical control surfaces in the winglets allow the RCS to be deactivated early in the descent, as the NASA/Langley Research Center has determined could be the case for a space shuttle orbiter outfitted with similar devices [1]. The OMS engines operate during ascent, so the mass of the OMS is included in the main propulsion system mass, unlike the Space Transportation System (STS) orbiter.

The wings are sized for reducing the planform loading during re-entry, but they are stressed to allow a large amount of lift during launch. Air-launched vehicles of this size have been proposed in the past [2] but those vehicles were intended for military missions and, as such, did not maximise payload.

Current Technology

As mentioned before, one of the programme tenets is the assumption that no new technology will be used. The authors believe that the current state of the art is such that a commercially optimised vehicle can compete favourably in the marketplace. Not requiring technology development also allows programme costs to be more accurately estimated so that cost uncertainty can be low enough for commercially acceptable risks. Development time is also shorter, so that capital investment can be recovered more quickly.

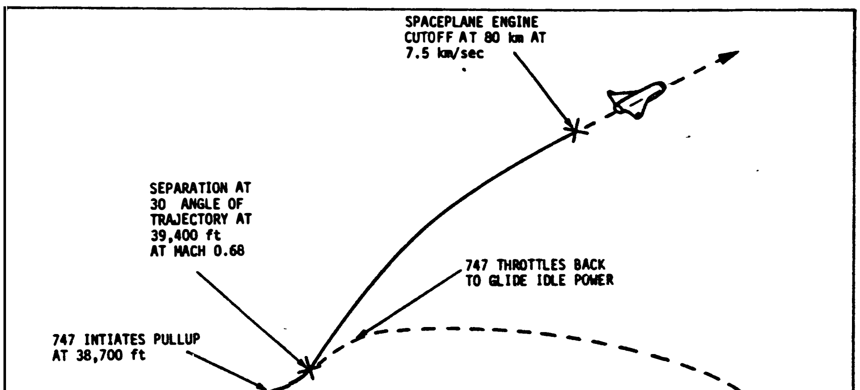
The second major tenet of this spaceplane concept is that it should be optimised for freight hauling. The space shuttle is badly hampered by its mandate to be all things to all potential users. A flight crew is not required for freight-hauling missions and the shuttle itself is nearly capable of going from launch pad to landing runway without crew attention. Adding crew only adds unnecessary mass.

Modern military aircraft and, to a lesser extent, commercial aircraft are flown by the pilot telling the flight computers what to do. There is no longer any direct mechanical linkage between the pilot and the aero control surfaces so it is only a small step to put this "supervisor" role on the ground. If the spaceplane is to carry passengers, this pilot-supervisor can be placed in the pressurised capsule in the vehicle's cargo bay along with the passengers. Thus, the pressure vessel and life-support equipment need only be carried when passengers are on board.

The last tenet is that the maximum landing payload be the same as the maximum launch payload. This is necessary for aborted launches.

Other design drivers, in addition to the above, include the carrying capacity of the Boeing 747 and the thrust of the spaceplane's main propulsion system. Main propulsion is provided by one Space Shuttle Main Engine (SSME) and six Pratt & Whitney RL-10

Fig. 2. Ascent profile.



engines. These provide a thrust-to-mass ratio of 1.45 at separation from the 747.

Ascent Profile

The ascent profile is depicted in Fig. 2. The 747 takes off and climbs to the west to maximise the time available for a return-to-launch-site abort. The airplane then executes a maximum-performance climb and does not loiter to pump propellants into the spaceplane or to achieve orbit phasing. This is important because the airplane carries very little reserve fuel. When the airplane reaches 36,000 ft, it initiates a turn to the east, then pulls up to a 30 degree trajectory angle. This pull-up manoeuvre cannot be done by a standard 747; some form of thrust augmentation must be provided, possibly by burning hydrogen in the turbofan's bypass duct [5], or by mounting eight military afterburning engines on the 747's wings instead of the four standard commercial ones.

The spaceplane's auxiliary engines are started and throttled to 40 per cent thrust before separation from the carrier airplane. This thrust is sufficient to overcome spaceplane drag, so the airplane need not be in a negative-g manoeuvre for separation.

After separation, the SSME is started and the RL-10's are throttled up to 100 per cent thrust. Fig. 3 shows spaceplane thrust, acceleration, altitude and velocity during its 5.5 minute engine burn.

At engine cutoff, the spaceplane is at the perigee of an 80 by 400 km orbit. A short burn is sufficient to circularise at the higher altitude. To maintain an acceleration level of less than 3.5 g, the SSME must be shut down approximately four minutes after separation, as it cannot be throttled to any arbitrarily low thrust level. Initial thrust/mass ratio of the spaceplane is 1.45, in order to minimise the gravity losses associated with lower thrust.

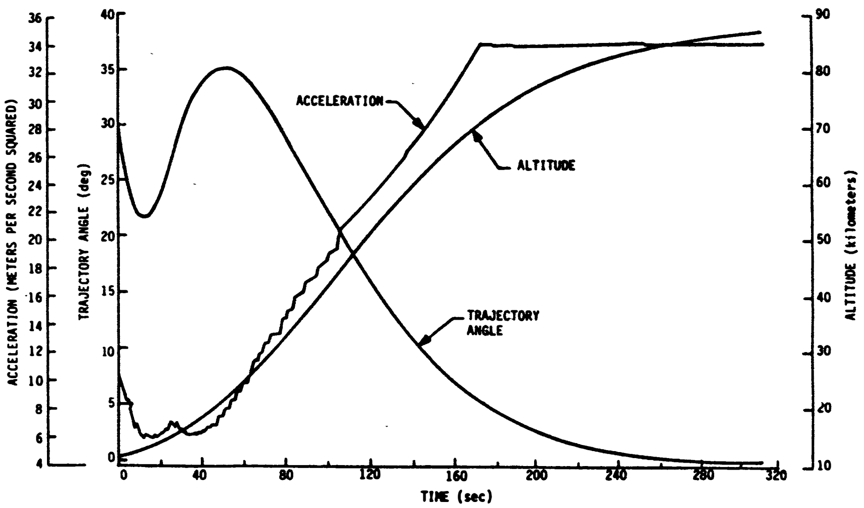


Fig. 3. Spaceplane Trajectory, Acceleration, and Altitude.

It must be emphasised that this vehicle flies a lifting trajectory and as a result receives a significant payload increase. During the initial pull-up from three to 10 degree angle of attack, the acceleration and trajectory angle actually decrease (this is also due in part to passing Mach 1, where lift and drag coefficients change significantly).

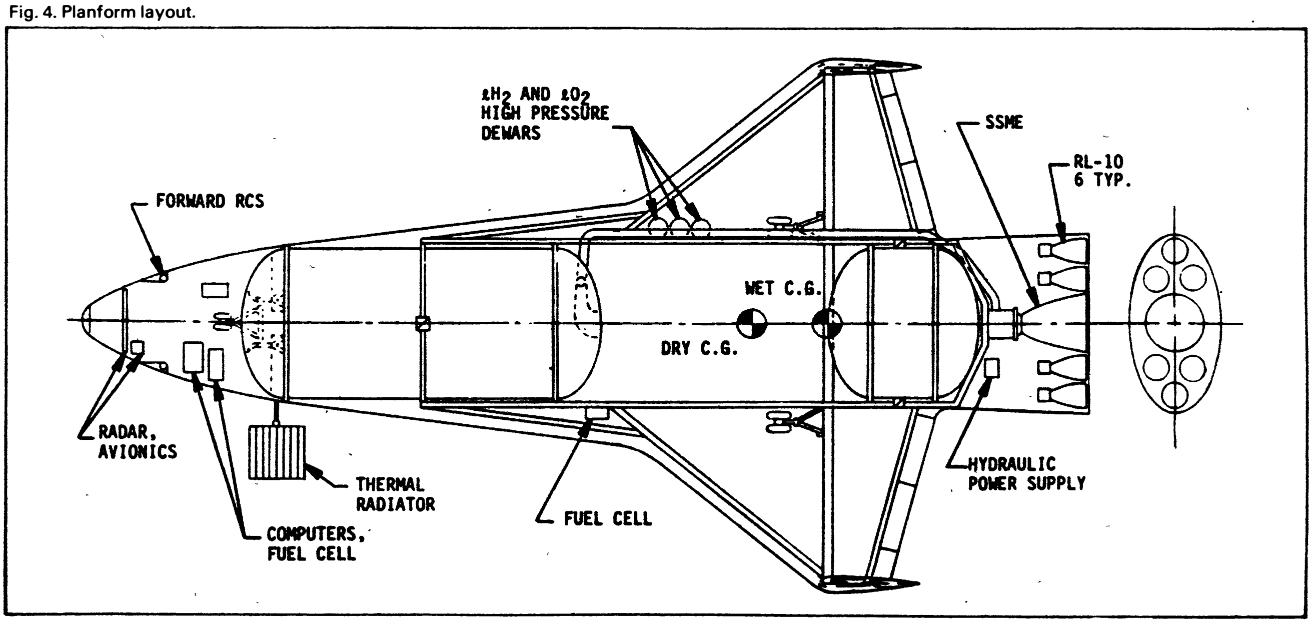
Return from orbit is similar to the space shuttle, except that planform loading is sufficiently low that metal skins may be adequate without insulating tiles. Planform area is nearly as large as the shuttle, but vehicle mass will be much less because:

1. It is unmanned, with no crew cabin, middeck, or life-support systems.
2. It is designed to carry only a 15,000 lb payload, compared with the STS 65,000 lb structural design.
3. The structure is simpler, with 50 per cent of the fuselage length being pressurised, load-bearing tankage. Also, the landing gear need support only one-third the shuttle's weight, max Q is much less, and vibration during launch is much less.
4. The engines are lighter. It has only one SSME, and the auxiliary engines are used for both main propulsion and orbital manoeuvring.
5. Recently available materials are stronger and lighter. Graphite/epoxy and aluminum/lithium can be used extensively.
6. There are fewer fluid systems and payload services. No ammonia, freon, hydrazine, methyl hydrazine, nitrogen tetroxide or nitrogen systems are incorporated.
7. Newer technology avionics are much smaller and lighter. Electric power levels will be lower without the crew and payload services.
8. The vehicle will always be handled horizontally. No structural provisions need to be made for vertical ground processing.

Characteristics and Systems

Planform and payload bay sections of the proposed spaceplane are shown in Figs. 4 and 5. Efforts have been made to place discretionary equipment in the

Fig. 4. Planform layout.



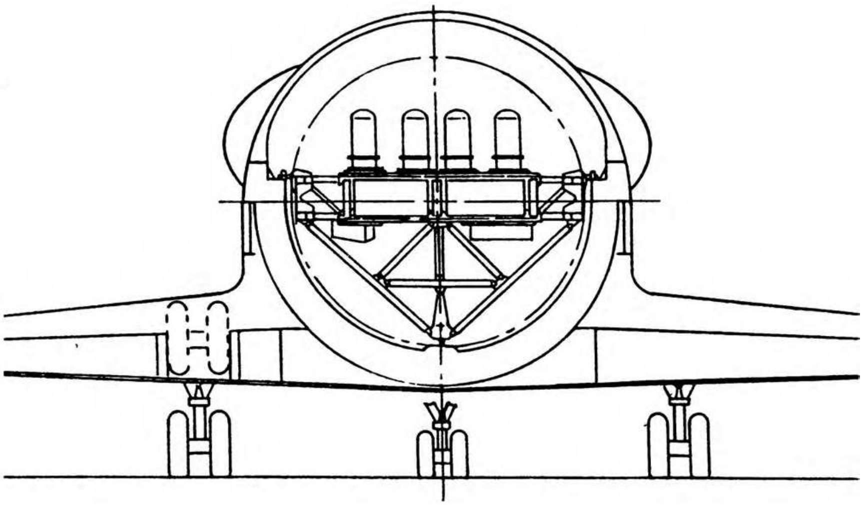


Fig. 5. Payload bay section.

nose of the vehicle so that the dry centre of gravity is near the centre of the payload bay. This will allow the vehicle to be aerodynamically stable with either a full or empty payload bay. The thermal radiator is located forward of the fuselage, near the heat-producing equipment. Thus, the payload bay doors need not be opened before the payload customer requests such operation. Further aerodynamic studies may show the desirability of using the same surfaces as radiators and canard control surfaces.

Payload structural interfaces are identical to those in the shuttle so that payloads designed for launch on the shuttle need not be redesigned for flight on this vehicle. Fig. 5 also shows a typical shuttle partial payload in the payload bay.

System Reliability

The staging techniques and winged configuration allow greater reliability than other vehicle systems. There have been six failures of major launch vehicles in the past two years, comprising two Ariane accidents, two Titan failures, and one each for the shuttle and Delta.

If the same component failures are stipulated in this spaceplane launch system, in no case is there any loss of hardware or crew. Two of the six failures were caused by solid rocket booster (SRB) explosions, and this system has no SRBs. The other four resulted from engine start failure or premature shutdown. A failure of this type, depending on which engine failed, and when, would result in the jettison of fuel and return of the spaceplane to land, either on the 747 carrier or as a glider.

Comparison with Similar Proposals

Many readers will notice that this spaceplane resembles others previously proposed, particularly the Pratt & Whitney/Boeing transatmospheric vehicle (TAV), and a similar concept done by Rockwell International [4].

However, it is important to bear in mind that those studies were not optimised for freight hauling. All were presented to a military customer and, as such, had system features that seriously detracted from payload carrying capabilities. Two of them were clearly stated to be technology development identification studies, rather than attempts to optimise the performance of current technology. The vehicle proposed by the authors of this article owes its relatively large payload lift capability at low cost to its optimisation for that job, with other reqirements held to be secondary.

The Next Step

The vehicle launch trajectory presented here was optimised by a computer program written by the authors. This program needs to be verified by comparison with an industry-accepted standard such as the POST program. Also, more detailed work, including stress analysis, needs to be done to carry the mass properties breakdown to a better level of detail.

Teledyne is currently looking for seed money from the US government to lend credibility to the concept, and also to more accurately determine performance and cost estimates. The intent is to then solicit commercial partners to build and operate the vehicle. To date, the company has presented its plans to NASA Marshall, NASA Langley, NASA Headquarters, the SDI organisation and Boeing.

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Dr. Ernst Stuhlinger is a consulting scientist for Teledyne Brown Engineering.

First Supers

by Joel W. Powell

When the Space Shuttle Enterprise touched down on the dry lakebed at Edwards Air Force Base on October 12, 1977, concluding the fourth Approach and Landing Test, it was almost 30 years to the day since Charles ("Chuck") Yeager made the world's first supersonic flight at the desert site. The milestone event was the first in a series of aeronautical breakthroughs that eventually led to a functional (albeit temporarily grounded) Space Transportation System some 40 years later.

Rocket Ships in the Desert

The orbiter Enterprise, with astronauts Joe Engle and Richard Truly aboard, was borne aloft and released for the glide tests from the back of a converted Boeing 747 jet. Three decades earlier, on October 14, 1947, a modified Boeing B-29 bomber took off from Edwards (then known as Muroc Field) carrying a tiny experimental aircraft in the bomb bay called the Bell X-1 rocket plane. At the controls of the X-1 was 24-year old Air Force Captain Charles E. Yeager, who was about to attempt mankind's first flight at supersonic velocity – faster than the speed of sound.

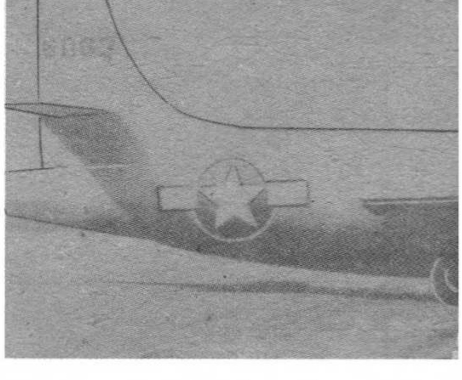
Sound energy travels at a rate of speed 1,220 kph at sea level and steadily decreases as the temperaturae falls with increasing altitude. The speed of sound is known as Mach 1 in recognition of the early studies of supersonic phenomena by the German physicist Ernst Mach in the nineteenth century.

Many engineers were convinced that the speed of sound represented an actual physical barrier through which no aircraft could safely pass. Predictions that an aircraft would become uncontrollable at Mach 1 due to compression of the air flow over the wings did not frighten the personnel of the X-1 project. Chuck Yeager was willing to risk his life to prove that flying at supersonic speeds was not only feasible but survivable as well.

The Bell X-1

Sporting a bright orange paint job to enhance visibility, the needle-nosed X-1 was a mere 9.1 m long (it would be swal-

Gen. Charles E. Yeager as he appeared in the early 1950



sonic Flight

lowed up in the Shuttle's cavernous cargo bay) and massed 6,129 kg with a full fuel load. Yeager always named the airplanes that he flew after his wife to bring him luck, and the X-1 also bore the legend "Glamorous Glennis", prominently displayed upon the nose.

The feeble jet engines of the day were not yet capable of achieving supersonic velocities, so Bell Aircraft installed a powerful Reaction Motors XLR-11 rocket engine in the X-1, the same powerplant that propelled the hypersonic X-15 on its initial flights 12 years later. The four chambered XLR-11 burned liquid oxygen and alcohol/water propellants and developed a total thrust of 26,880 Newtons.

Captain Yeager was protected during each flight by the first primitive high altitude pressure suit specifically developed for the X-1 project by the David Clark Company. Crash helmets had not yet been invented, so the pilot improvised by fitting the hard-shell head gear worn by tank crews over his leather flying helmet and oxygen mask. Unlike today there were no backups for critical mechanical systems, and an emergency landing in the X-1 was the only escape option available because there was no ejection seat.

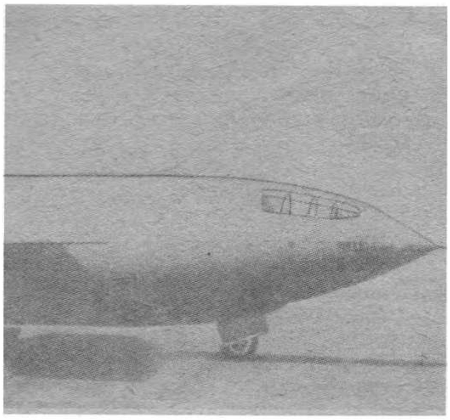
Twenty Seconds at Mach 1

Boarding the rocket plane after the B-29 was safely aloft, Yaeger faced a potentially serious situation. The pilot required the use of his right arm to secure the hatch, but Yeager's right arm was practically immobilised as a result of two broken ribs suffered in a riding accident. Captain Yeager managed to produce enough leverage to seal the hatch by using his left arm and a section of broom handle that he had hidden in the cramped cockpit.

After an uneventful pre-launch checkout, the rocket plane dropped away from the B-29 at 10:26 am to begin Yeager's ninth powered flight in the X-1. Just four days earlier Yeager came tantalisingly close to flying supersonic when he reached a top speed of Mach 0.997.

With two rocket chambers firing, the X-1 streaked skyward at a 45 degree angle and rapidly outpaced the two P-80 chase planes. The X-1 continued accelerating as the severe buffeting and loss of aerodynamic control experienced on previous flights began to appear at Mach 0.7.

s, posing in front of the advanced X-1A rocket plane. *USAF*



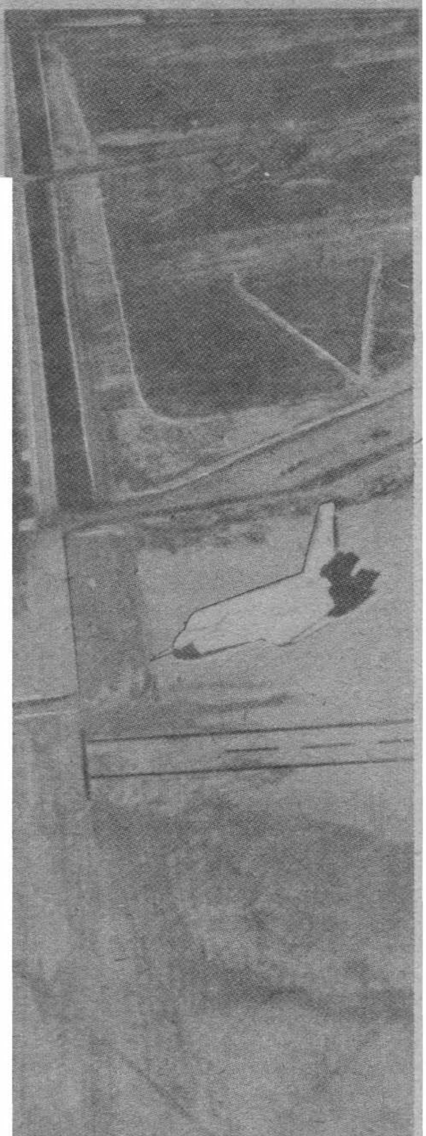
The needle-nosed configuration of the X-1 rocket plane was derived from the shape of a 50-calibre machine gun bullet. *USAF*

Noting a small oxygen pressure drop, Yeager briefly cut off two of the four chambers until the pressure returned to normal. One chamber was re-ignited, and at Mach 0.96 the buffeting began to diminish and aerodynamic control gradually returned. The machmeter crept steadily forward to 0.98, then suddenly moved right off scale.

Without a ripple the X-1 had passed through the dreaded "sound barrier" and achieved a final velocity of Mach 1.06 (about 1,125 kph). At the peak altitude of 13,100 m Captain Yeager was practically on the edge of space. The sky darkened and the Moon and stars became visible in the daylight.

The historic first sonic boom reverberated above the tiny desert community of Victorville to herald the dawning of a new era in aviation. Thirty-four years later another sonic boom over the desert would announce the return of the first rocket-powered aircraft from orbit: the Space Shuttle Columbia.

The 14 minute flight of the X-1 concluded with a perfect dead-stick (without power) landing on the dry lakebed, just as the Space Shuttle was destined to perform there three decades later. Perhaps the supersonic flight of the X-1 helped reinforce the opinon of early space visionaries that winged re-entry vehicles were the only practicable means of returning from orbit (witness the ill-fated Dyna-Soar orbital glider of the 1960's). Only after three generations of ballistic return capsules were flown by NASA was the Space Shuttle able to prove that the visionaries were right.



Completing a glide test flight on October 12, 1977, orbiter Enterprise approaches the same lakebed runway at Edwards AFB where the first supersonic flight was completed 30 years before. NASA

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BUSINESS ARENA

The January 1985 Ministerial Council of ESA Member States defined ambitious plans that aimed to make Europe a major space power. At the follow-on meeting in November 1987 these plans were up for ratification. The UK's signalled withdrawal from at least two major ESA projects, Ariane 5 and Hermes, has received much publicity but is unlikely to affect ESA's intentions.

In addition to ESA, many national and international organisations contribute to Europe's overall space activity, the scale of which over the next ten years has been analysed by *Theo Pirard* from a financial viewpoint. His report discloses that as well as the upcoming major ESA projects, which so readily make the headlines, a large part of European space activity will involve science and applications sponsored by a diversity of national and international organisations.

European Space Business, 1987-1996

Europe's International Activity

Some 150 to 200 spacecraft will be launched by Europe and developed with significant participation by European industry during the next ten years according to actual plans and projects in hand. The total expenditure to be made by European States in international projects involving the preparation and development of satellites, orbital payloads, launch systems, spacecraft for science, technology and applications will be at least 25 billion accounting units (AU) for the period 1987 – 1996.

The European Space Agency (with 13 Member States, one Associate Member and one Cooperating State) has a leading role to organise, manage and develop innovative and ambitious space systems. The following data show the percentage of the total expenditure taken up by each item:

- Main programmes (Ariane 5/Columbus/Hermes) 12,000 MAU (48%)
- Science & Technology (from Hipparcos to Cluster, from Olympus to PSDE, from Meteosat to ERS-2, from Spacelab to Eureca, plus international ventures) 4,500 MAU (18%)
- Data Relay System for European spacecraft (DRS) 500 MAU (2%)

Total 17,000 MAU (68%)

The Eutelsat Organisation for European telecommunications satellites (with 26 national shareholders in Europe) is using ESA services for the ECS or Eutelsat I system; however, it is fully resposible for the purchase, management and operations of the Eutelsat II system.

- Eutelsat II expenditure (four to eight satellites) 500 MAU (2%)

The Eumetsat Organisation for the exploitation in Europe of meteorological satellites (with 16 Member States as shareholders) will use ESA services to operate its "first-generation" weather satellites, or Meteosat Operational Programme (MOP); during the 1990's, it plans to continue operations with advanced "second-generation" spacecraft.

The Inmarsat Organisation for global maritime satellite communications – to be extended to aeronautical services in the near future – (with 48 national shareholders) is leasing two ESA Marecs spacecraft for Atlantic and Pacific traffics; ESA is using Marecs capacity for tests of mobile satellite services in the framework of the Prodat/Promar programme. For the Inmarsat II generation spacecraft, the organisation contracted a European prime contractor, British Aerospace (associated with Matra), for an initial batch of three satellites, plus options for a further six spacecraft with some improvements for aeronautical links (Inmarsat IIA). The Inmarsat II purchase can represent business for European industry of up to 250 MAU, including launch operations.

National Roles

Five European countries have the industrial capacity required to be prime contractors for space systems. Until now, they have supported a strong national effort in space science and technology and are operating or preparring to operate domestic space systems having applications to mainly communications and broadcasting.

France in space technology has been represented since 1962 by CNES (Centre National d'Etudes Spatiales) which had a budget approaching 1,000 MAU in 1987 and is supporting a quarter of the ESA budget. Its space programme is especially complete, from technology development to transportation marketing and applications commercialisation. Outside of its significantly strong contribution to ESA programmes, CNES is largely favouring original applications and international cooperation with the USSR and USA. Military space activities also find place in the French programme.

- Commercial and industrial applications (Telecom I/II, Spot system, TDF-1/-2 for DBS, CLS/Argos, Sarsat) 2,000 MAU (8%).
- Worldwide cooperating ventures (manned spaceflights, interplanetary probes, Topex/Poseidon) 250 MAU (1%).
- Military space systems (Syracuse, Helios) 1,000 MAU (4%).

Total 3,250 MAU (13%)

Germany is organising its space policy through the Federal Ministry for Research and Technology (BMFT), with responsibilities given to the German Aerospace Institute (DFVLR).

- Research and Technology mis-

sions based on the utilization of the NASA Space Shuttle (Spacelab D2, Astro-SPAS, DOM-SPAS, Eureca) and on the cooperation with NASA (Rosat, Galileo, GRO) 600 MAU (2.5%).
- Domestic applications spacecraft, with communications and broadcasting systems (Kopernikus/DFS, TV-Sat) 1,000 MAU (4%).

Total 1,600 MAU (6.5%)

Italy has a regularly updated National Space Plan (PSN) under the management of CNR (Consiglio Nazionale delle Ricerche). It has recently announced plans to establish a national space agency or ASI (Agenzia Spaziale Italiana).

- Science and Technology space systems (IRAS, Lageous 2, TSS, SAX, and UT-X, with NASA 400 MAU (1.5%).
- Communications and Broadcasting satellites (Italsat, SARIT or SICRAL/Argo) 300 MAU (1.2%).

Total 700 MAU (2.7%)

The United Kingdom space industry has much know-how in space applications, particularly in communications and remote sensing systems. However, because of budgetary restrictions, it has lost opportunities for space technology development. The British National Space Centre (BNSC) was set up in November 1985 as a focus for British space policy. BNSC's task was to formulate and implement a National Space Plan, covering domestic programmes and UK's participation in ESA but its implementation suffered a serious setback in August when the Government decided that expenditue would not be increased.

- Space applications for civilian purposes (Canadian Radarsat, TSS/CERS,) 150 MAU ? (0.6%).
- Military spacecraft (Skynet IV/NATO IV) 500 - 1,000 MAU (2 - 4%).

Total 650 - 1,150 MAU ? (2.6 - 4.6%)

Sweden and its aerospace/electronics industries are represented in space by the Swedish Space Corporation (SSC), a state-owned limited corporation since 1961 under the Ministry of Industry. It operates the Nordic Esrange facilities to launch sounding rockets and track satellites, and to collect data from remote sensing spacecraft. It manages the Swedish contribution to ESA and Swedish cooperation with France and USA. For Televerket, the Swedish PTT administration, it is developing the Tele-X system for communications and broadcasts. With China, it is preparing the Mailstar project.

- Swedish investment to cover national space systems (Tele-X, Mailstar) 300 MAU (1.2%).

Commercial and Other Activities

In Europe, the commercialisation of space systems is coming from the French CNES with governmental support:

- Arianespace (space transportation sevices) operates a family of launch vehicles developed with public funding through ESA and CNES 5,000 MAU (20 %).
- SPOT Image (remote sensing from space) using the Spot spacecraft developed with public investments from France (CNES), Sweden (SSC) and Belgium (SPPS/SPO) 500 MAU (2 %).
- Other commercial operators of space applications (CLS/Argos for data collection, Telespace and Locstar companies respectively for direct TV broadcasts and for radiodetermination services) 500 MAU (2 %).

For satellite communications and TV broadcasts, the public PTT administrations are investors and opérators of space systems for regional and domestic purposes:

- Eutelsat, exploiting the Eutelsat I system and preparing the Eutelsat II system, studying the Europesat DBS project. 500 MAU (2 %)
- French DGT (Direction Generale des Telecommunications), operating the Telecom I system, designing the Telecom II system 500 MAU (2 %).
- The German Bundespost, resonsible for the management and operations of the national TV-Sat system and of the Kopernikus/DFS system 900 MAU (3.6 %).
- The Italian Telespazio, developing the Italsat system and studying the SARIT project for DBS operations 200 MAU (0.8 %).
- Scandinavian Notelsat (with Swedish and Norvegian PTT's as shareholders) operating the Tele-X spacecraft 250 MAU (1 %).

Europe's private enterprise in space applications in taking off cautiously with satellite technology imported from US industry. Does this fact mean that European space industry is unable to fulfil the precise requirements of a private company which operates for profit. Private requirements in space technology are marketing flexibility, satellite reliability and delivery/launch punctuality. There are now two completely private ventures in Europe – just agreed by the relevant government authorities – that are seriously developing their satellite systems for TV broadcasts from space:

- The Luxembourg Astra system, managed and operated by the SES (Societe Europeenne des Satellites) company, developed with RCA/GE Astro Space communications satellite for up to 16 TV channels (medium-power broadcasts) 180 MAU (0.7 %).
- The British Satellite Broadcasting consortium, formed by many broadcasters and electronics manufacturers, obtained the IBA franchise to operate three DBS channels for 15 years, contracting Hughes and McDonnell Douglas for two high-powerful TV spacecraft (direct reception signals). 400 MAU (1.6 %).

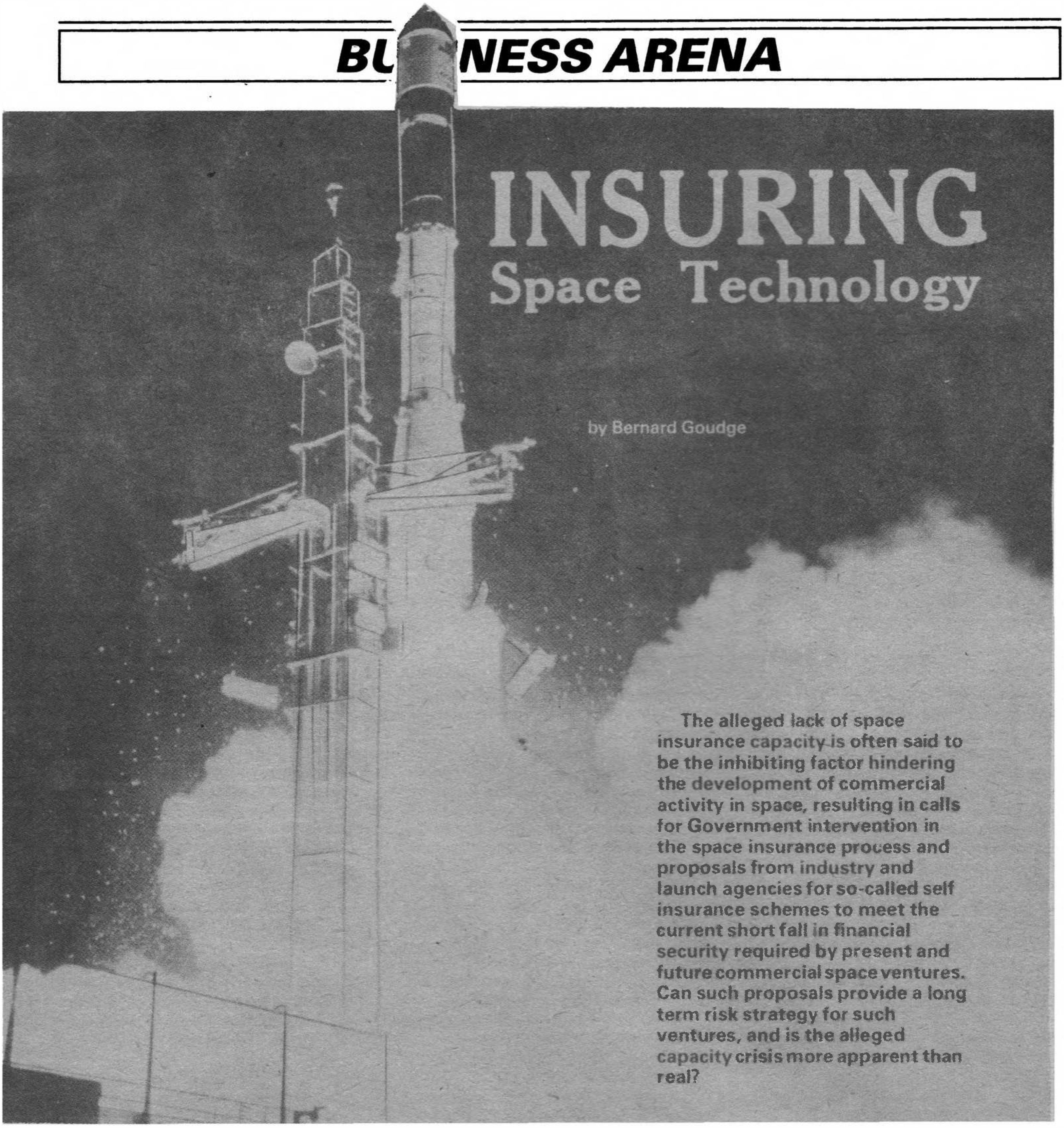
In the next five years until the end of this decade, a European "star wars" will break out between the state-owned TV-Sat (Germany) and TDF-1 (France), the privately-funded Astra-SES (Luxembourg) and BSB (United Kingdom), and the public Eutelsat II system (European PTT's). This battle over Europe will be more audiovisual than technical: European TV viewers will decide the winner according to the most attractive programmes.

The military aspects of space systems are just burgeoning in two European countries and are stimulating both political and industrial activity in Europe:
- The French Ministry of Defence is operating the Syracuse I communications satellite system, developing the improved Syracuse II system and the Helios spy-satellite family for the 1990's. 1,000 MAU (4 %).
- The British Ministry of Defence is preparing the Skynet IV communications satellite system and promoting the Nato IV communications satellite system. 500 – 1,000 MAU ? (2 - 4 %).

In summary, practical applications related to space systems in Europe have the following breakdown:
- French-CNES initiated commercial ventures. 6,000 MAU (24 %).
- Public-funded communications-TV networks. 2,350 MAU (9.4 %).
- Private-owned enterprises for TV broadcasts. 580 MAU (2.3 %).
- Governmental military spacecraft. 1,500 MAU (6 %).

Total 10,430 MAU (41.7 %).

In the near-term future, new initiatives for the exploitation of space applications, with the prospects of economical or strategic benefits, may appear. It is quite possible that 50 per cent of European investments in space systems during the next decade will be made for commercial, private and military activities.



INSURING
Space Technology

by Bernard Goudge

The alleged lack of space insurance capacity is often said to be the inhibiting factor hindering the development of commercial activity in space, resulting in calls for Government intervention in the space insurance process and proposals from industry and launch agencies for so-called self insurance schemes to meet the current short fall in financial security required by present and future commercial space ventures. Can such proposals provide a long term risk strategy for such ventures, and is the alleged capacity crisis more apparent than real?

Lift-off of Ariane mission V19. *Arianespace*

Rarely, if ever, can a new class of insurance business have had such an optimistic birth, a turbulent childhood, and a subsequent problematical life expectancy, as has space insurance.

Lustily conceived in the halcyon days of the 1970's, weaned on the euphoria of the successful Apollo missions, nurtured on the promise of the US space shuttle and fed an apparently rich dollar diet, the infant business looked certain to enjoy a thriving growth to a tall and strong financial maturity.

But the events of the early 1980's were to deny this expected life style. The resulting appalling financial results for the insurers overall are well known. The numbers flowing from the various failures and their resulting losses have been the subject of constant and continuing intense scrutiny by all the parties involved. They have been analysed, dissected, construed, misconstrued, explained, denied, accepted, rejected, and made the subject of endless commentary, interpretation and prognostication. At one time, the appearance of space 'technicians' and 'expert advisors' seemed to be a major growth industry in the insurance markets!

By the end of 1984 individual and corporate perceptions of the situation seemed to vary in direct proportion to the perceiver's financial involvement (or lack of involvement) in the evolving overall failure scenario. These perceptions also appeared to be coloured by the viewing angles, which produced differing conclusions from the same data base depending upon whether the viewer was an insured user, a launch vehicle or spacecraft manufacturer, a launch agency, insurance broker or space underwriter. However, whatever the underlying reasons, one salient fact was not in dispute – the underwriters had collectively bet their shirt – and lost!

But has all this analysis, application of hindsight and soul searching

This article is based on a presentation to the International Bar Association, September 17, 1987, London, UK.

produced any tangible positive results in evolving a long term strategy for the development of a stable space insurance market with sufficient capacity to meet the needs of those embarking upon commercial ventures in space to the end of the century – and beyond?

In 1982 it had been possible to place up to US$ 250,000,000 launch insurance for any one launch. By the end of 1984 this capacity had dropped to not more than an estimated US$ 90,000,000 for any one launch, remaining at around this figure for 1987. Thus, whatever market stability has been achieved, the price has been the loss of some 64 per cent of the launch capacity which previously existed.

The Shuttle Launch Services Agreement liability facility when first placed had a limit of US$ 750,000,000 for any one occurrence. Now it is not possible to obtain more than US$ 300,000,000 for the same type of coverage, again, a loss of some 60 per cent of the previous capacity.

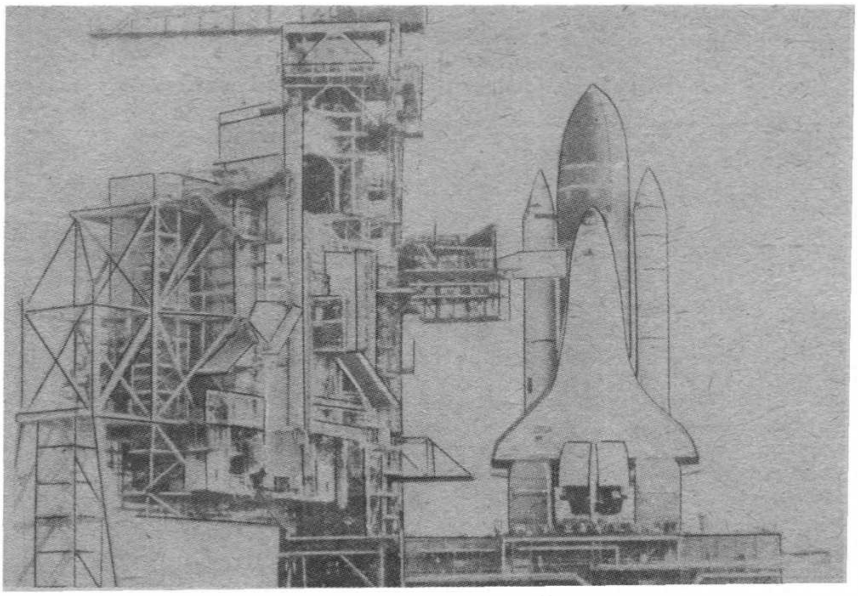
Against this background, certain events occurred which were to further influence the position. First, the tragic loss of Challenger on January 28, 1986, followed by the failure of Ariane V18 on May 31, 1986, the loss of a Titan on April 18, 1986, a Delta on May 3, 1986, and an Atlas on March 26, 1987.

The resulting grounding of the Western world's major launch vehicles and the virtual withdrawal of the US shuttle from future commercial spacecraft launches provided not only an imposed pause for serious reconsideration of all aspects of operations in space, but also gave rise to the second major debate which was to influence the provision of space insurance, particularly for spacecraft launch and commissioning risks.

The second debate concerned the arguments for and against the provision of expendable launch vehicles by commercial undertakings, instead of government agencies such as NASA.

As this debate progressed, it was possible to detect some apparently curious anomalies in the arguments advanced to support the various approaches suggested by some of the parties concerned in seeking solutions to the various aspects of the overall problems.

The shuttle failure in particular precipitated an on-going consideration as to the development direction in which commercial private enterprise launch capability in the United States should proceed, as well as demonstrating previously unknown and undetected flaws in the Government space agency infrastructure and operations.



Worldwide capacity for satellite launch insurance is now some 60 per cent less than at the time of the above picture, taken in August 1984 prior to the launch of Discovery on mission 41-D. *NASA*

Arising from this overall debate, it was possible to detect two distinct lines of approach to the question of insurance, having regard to the reduced capacity, increased pricing and the general tightening of terms and conditions.

The first favoured the relaunch guarantee, retained risk, self-insurance or mutual type of approach. The second approach advocated Government intervention – in other words, the use of tax-payers' dollars as insurance of "last resort". This second approach was given voice in 1986 before the Sub-Committee on Space Science and Applications of the Science and Technology Committee of the United States House of Representatives, when significant speakers from Ford Aerospace and Communications Corporation, the Space and Communications Group of Hughes Aircraft Company, Martin Marietta, General Dynamics. McDonnell Douglas Astronautics, Transpace Carriers and American Rocket Company advanced their views.

The hearings were primarily concerned with the presentation of views and suggestions as to how best to deal with the so-called launch vehicle crisis and, given the withdrawal of the shuttle from the commercial satellite launch role, what could be done to establish private enterprise commercial launch capability, and what should be the launch vehicle 'mix' to achieve this?

Whilst much of the presentations centred around the desirability or otherwise of continuing to depend upon vehicles which in some instances represent 25 year old technology versus the need to develop new vehicles with new technology, there was general concensus upon one key issue, namely, the need to remove Government from the commercial launch process, and for a realistic pricing structure for launch services to eliminate 'unfair' Government subsidy advantages.

Government intervention in the commercial market place is seen as inhibiting, producing artificial conditions which often deny reality, and subsidy is a means of prolonging such unreality, to the detriment of required solutions to the underlying problems once they are fully manifest and understood.

Proposals for retained or mutual type insurance usually arise as a response to increased premiums and restricted terms for a section of business which has proved unprofitable to the insurers over a period of years, during which the insured population has, for whatever reasons, enjoyed the benefits of a soft market.

Some measure of retained risk is an accepted way by which individual organisations seek to reduce premiums payable, and would normally be related to the organisation's financial capacity to economically withstand the retained loss, if the need arises.

It can rarely, if ever, be a long term solution to the fundamental financial future requirements of a whole industry, particularly one which is committed to ever increasing investment on a long term basis in a high risk business.

Self insurance and mutualisation programmes usually proceed from a belief that those participating will somehow enjoy a better loss experience than the underwriters who

are requiring increased premiums, as a result of the previous loss experience of the same group. There is surely an element of self delusion and fallacy here? In any event, however much self insurance or mutualisation occurs, at the end of the day comes the realisation that there has at all times to be sufficient funds to pay for the inevitable losses. It may be comforting to have a low percentage rate for premium purposes, but claims arise in dollars, not in percentages!

Over the past year we have moved from the position where Arianespace was the only launch agency offering relaunch insurance, to a situation whereby virtually all the major launch vehicle manufacturers and launch agencies, real or potential, are including some form of launch insurance as a contractual option to users. Almost all of these schemes are said to be in response to the alleged capacity and price problem in the insurance markets, and are offered at prices considerably below those currently quoted by space underwriters – although it has to be said that the coverage may well differ between the two sources.

The Soviet Union and The People's Republic of China are now also making serious efforts to enter the international commercial launch market, and are using State insurance institutions as the vehicle for launch insurance packages.

Finally, there is the Space Mutual Insurance Association (Bermuda) which is said to be the first insurance group driven directly by user launch insurance concerns, and designed to insure satellite users launching on Ariane rockets on a mutual basis – again with the objective of achieving cost reductions over market rates.

It is becoming increasingly difficult to escape a conclusion that a situation is now developing where choice of launch vehicle by a satellite operator may not only be governed by its timely and reliable availability, and its suitability for the proposed mission, but is now in danger of being influenced by the availability of alleged cheap insurance packages.

Insurance, therefore, from being the means whereby the financial risk is extracted from commercial space ventures, becomes simply a marketing tool in the competition to sell hardware and services.

Its use as a marketing tactic in such circumstances is understandable, but what of this tactic in a strategic risk management context? All of these schemes are said to be founded in an alleged need to generate capacity for launch insurance at a price the customer is willing to afford and as an answer to the insurance markets' allege inability to do so. Yet all rely in the end for their continuation upon capacity from the existing markets by way of reinsurance. Even the insurance companies of the Soviet Union and the People's Republic of China may well look to the international insurance markets for reinsurance support. Little, if any, new capacity is generated by this means, and any proposal that takes premium from the regular space market simply delays the required

Third Eutelsat Satellite Now Operational

The third satellite of the European Telecommunications Satellite Organisation (Eutelsat), which has 26 member states, entered service over Europe on November 1, 1987.

ECS-4, like the other first-generation satellites of the Eutelsat network, was built and launched under the responsability of the European Space Agency (ESA). Launched by Ariane on September 16, it underwent successful in-orbit testing during October before formal acceptance by Eutelsat. The satellite is now called Eutelsat I-F4.

Stationed at 10 degrees East, eight of the satellite's transponders will be transmitting national and international television programmes, as well as Danish national telecommunications.

Eutelsat now has three operational satellites in orbit, with a total capacity of over 27 transponders. Its next satellite will be launched in 1988 and will come into operation in the autumn.

New High Power Communications

The HS 601 body is composed of three modular structures: primary, carrying launch vehicle loads and propulsion subsystem; a honeycomb shelf houses bus electronics and battery packs; another honeycomb shelf holds the communications equipment and isothermal heat pipes. The modular approach will allow work on the three structures to proceed in parallel, thereby shortening manufacturing time.

market development and stabilisation.

Long term solutions to the so-called capacity problem will not be found by disparate ulilateral approaches heavily biased towards short term commercial advantage.

It is highly doubtful that the 'one failure deductible' provision which appears to be a feature of most of the schemes previously mentioned will do very much to restore confidence expectations to previous levels and beyond, when what the insurers are really looking for is evidence of improved quality and reliability in the products and technology, what steps the manufacturers and launch agencies are taking to achieve this, and when and to what extent improvements in success ratios may be expected.

In the United States, an end to the seeming continuing vacillation within the Administration over future space policy would undoubtedly assist the process.

It is readily apparent that the space industry is fighting hard to recover from a series of disasters, and is seeking new directions and philosophies to bring the overall space programme back on course. It is absolutely vital that for the sake of so-called short term solutions, international space insurers should not feel alienated from this process, but should be considered an integral part of the overall strategic approach at all stages.

Satellite

Hughes Aircraft Company is to develop a new body-stabilised satellite – the HS 601 – to meet high-power communications needs into the 21st Century. The first of the new line is expected to be ready for service by 1991.

Hughes Aircraft Company, a unit of GM Hughes Electronics, is predicting an increase in satellite communication applications requiring spacecraft generation power levels as high as 6,000 watts, in both commercial and government markets. A medium-sized satellite of today generates about 1000 watts.

Such applications include broadcasting television programmes directly into homes through antennae one foot in diameter; two-way mobile communications to cars, trucks, trains and aircraft; and private business communications networks through very small aperture terminals (VSAT).

The HS 601 represents Hughes first production body-stabilised (three axis) satellite.

While certain versions of the HS 601 could measure 85 feet across the two solar arrays, the satellite will compact to a launch configuration approximately eight feet square, matching the envelope and load requirements of today's launch vehicles, including Titan, Atlas Centaur, Ariane, Long March and the Space Shuttle.

Benita C. Hayes of the Systems Analysis and Integration Laboratory briefs workshop attendees in Marshall Space Flight Center's full-scale engineering mock-up of the permanently manned Space Station's US Laboratory Module *NASA*

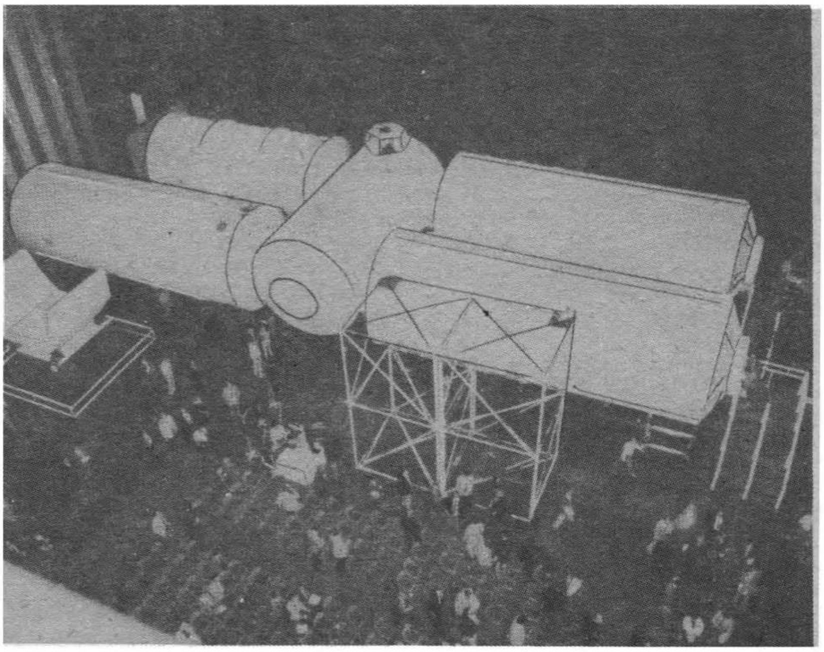
Space Station Workshop

More than 100 representatives of space agencies in Europe and Japan, NASA officials, US astronauts, designers and potential users of the permanently manned Space Station met at NASA's Marshall Space Flight Center in Huntsville, Alabama, in early October to participate in a Space Station Laboratory Workshop.

Workshop attendees toured full-scale engineering mock-ups of the US Laboratory Module and Habitation Module to see first-hand what living and working in the Space Station will be like.

Attendees received briefings on the Space Station Laboratory Module and discussed its potential use as well as how the mockups themselves may be used during the detailed design and construction of the Space Station. They also were briefed on User Operations, Logistics Interfaces, Standard Rack/Utility Provisions and Selected User Accommodations in the US Laboratory Module.

Participants at the Space Station Laboratory Workshop gather around Marshall's full-scale engineering Space Station mock-ups. *NASA*



IAF President Dr Johannes Ortner (left) with Mr. John Butcher MP (centre), Parliamentary under-secretary of State for Industry, and Mr. Len Carter during the joint Government/BIS evening reception.

The Brighton Corn Exchange provided an ideal setting for the two evening receptions. The Banquet was also to have been held here.

BIS staff members and some of the Congress helpers during an evening reception. *From left:* Gary Marsland, Clive Simpson, Shirley Jones (foreground), Margaret Simpson, Suszann Parry, Rod Woodcock, Tina Buttinger, Marilyn Marsland and James Goddard. *P.J. Fulford*

Congress 'Thank You' Letters

Many letters and comments were gratefully received by the Society in the days following the IAF Congress and SPACE '87 Exhibition:

Congratulations to the British Interplanetary Society on the Brighton Congress! I think it was a great success, much enjoyed by all the participants, with the hurricane providing a memorable finale. Thank you too for the splendid reception in the Royal Pavilion and the commemorative plate. Of all the conferences I have attended, this will be the most enduring in memories.

DESMOND KING-HELE
Royal Aircraft Establishment
Farnborough, Hants.

I thought the Exhibition was extremely well organised and very interesting, as did everyone I spoke to. The quality of the exhibits was very impressive and I shall be giving a glowing report.

IAIN MacDONALD
Commercial Attache
Government of Quebec

I am sure others will express their thanks to you for a well organised SPACE '87 but I should like to add my thanks for the hard work you all put in to make the event a success. I much appreciated the assistance given to me personally and Marconi in general. Thank you.

PETER WILDISH
Marconi Space Systems

All at the BIS are to be congratulated for the professional way this event was organised. It has been a great pleasure working with you over the arrangements. We are upset that your conference became a casualty of the hurricane gale and I sincerely hope that your delegates will not allow the cancellation of the banquet to mar their thoughts on a very successful week.

CELIA ADAMS
Conference Officer
Brighton Centre and Dome Management

I am truly sorry the weather last week was so flagrantly uncooperative. Most of us were particularly upset that your excellent arrangements for the gala banquet were so sadly frustrated. Despite the unfortunate weather, I believe most delegates found the Congress most useful and informative. Best personal regards.

JERRY GREY
Past-President
International Astronautical Federation

May I compliment you on a most illuminating and enjoyable IAF meeting in Brighton. It certainly contained many useful sessions and provided an excellent benchmark of the space programmes at this time.

IAN L. THOMAS
Woking, Surrey

The Congress was very successful and the Technical Sessions were excellent and with record attendances.

L.R. SHEPHERD
Dorest, UK

I was disappointed not to be able to attend the reception in Brighton to mark the opening day of the IAF Congress on October 12. As you will have heard, I was called at short notice to attend an urgent meeting of Airbus Ministers in Brussels the same evening. I was however very glad to learn from my colleague John Butcher that the reception went well.

KENNETH CLARKE
Minister of Trade and Industry

I was very glad to hear that the Congress was a great success despite the incomprehensible performance from the Government.

Lord SHACKLETON
House of Lords

Very many thanks for allowing our party to experience the SPACE '87 Exhibition at Brighton. The organisation was superb and, in every respect, a real credit to the Society. Everyone of our party was thrilled to meet the astronauts and many in our party will, I am sure, retain special memories of the day, possibly for the rest of their lives.

JOHN W. BURLEY
Exeter College, East Devon

I was one of about 30 boys from the lower sixth of Emanuel School, Battersea Rise, who attended the SPACE '87 Exhibition. I am writing to tell you how I enjoyed it. I was very happy to see representatives from many companies and organisations willing to see us. At one of the stands I noticed an account of the Daedalus project which I was fascinated by. I thought that it was wonderful that people could look into the future with such initiative.

A.S. AHMAD
London SW18

My congratulations on a well run and well received Congress. The meeting and meeting places were well organised, diverse and most interesting. I particularly appreciated the emphasis on crossover between disciplines.

KENNETH M. JONES
Massachusetts, USA

My wife and I attended the SPACE '87 Exhibition and had a most enjoyable time. The exhibition was really splendid and the exhibitors charming and interested in those of us attending, answering questions and providing technical information and numerous souvenirs. We were particularly impressed with the friendly reception we received at the BIS and ***Spaceflight*** stands and would like to thank all those concerned.

T.J. WAYNE
Kent, UK

I should like to take this opportunity of offering my congratulations to the BIS on what was reportedly an excellent IAF Congress and Space Exhibition.

GEOFF DAVIES
Roleystone, Western Australia

Congratulations on the terrific job you did organising the IAF Conference and SPACE '87 Exhibition. By all accounts it was a great success and will be memorable despite the hurricane that blew through on the last day.

JACK SCHMID
NASA Exhibits Coordinator

I would like to take this opportunity to congratulate the Society on its magnificent efforts in Brighton, especially with regards to the souvenir newspaper.

EDWIN A. KAYES
Data Recording Div.
Thorn EMI

On behalf of our Society, may I congratulate you for the successful staging of the IAF Congress at Brighton inspite of the non-cooperative weather. I also want to thank you for the arrangements provided to our Society for promoting the Bangalore Congress.

C.R. SATHYA
Astronautical Society of India

Hurricane Storm

The Society escaped relatively unscathed from the hurricane force winds which left a trail of devastation throughout South-Eastern England during the night of October 15-16.

Subsequent torrential rain, however, penetrated the roof of the HQ building causing considerable damage in some of the upper rooms.

Flooding also caused a potentially serious problem for the printer of ***Spaceflight*** in Aylesbury, who had just completed the November issue. However, all but a few copies were saved, with distribution largely unaffected.

One concerned member, John Fadum from Florida, wrote: "Please accept my condolences for absolutely horrible weather that you have been having the last few days. I saw the storm damage to Central London on TV and sure hope that the BIS HQ is in better shape. I am anticipating, with dread, a report in ***Spaceflight*** (unless the BIS Council must suspend publication for a time: I sure hope not, but would certainly understand if you do)."

The storm, the worst to hit the south coast of England since 1703, also caused severe damage at Brighton, being most intense during the early hours of Friday October 16, the last day of the meetings programme of the IAF Congress. Fortunately, the mains power was restored in time for the technical sessions to start on time at 9 am.

In spite of the loss of power during the early hours of Friday, the Society's souvenir colour newspaper, 'Congress News', which was being printed overnight in Brighton, was available to Congress participants within two hours of its scheduled time.

At the peak of the storm in the early hours of the Friday morning the BIS kiosk in the foyer of the Brighton Centre was blown down and showered with glass as one of the large plate glass panels of the front facade of the building crashed in.

Unfortunately the mains power in Brighton failed again at the end of the afternoon not to return until later in the evening when it was already too late to go ahead with the Congress Banquet which the Society had organised. The cancellation of this was a great disappointment to all concerned. Refunds were sent to all who purchased tickets.

Arthur C. Clarke

We extend congratulations to Arthur C. Clarke, Honorary Fellow of the Society and a past chairman, who celebrates his 70th birthday this month. We are pleased to say that he is as active as ever. He has written a book for a film called *Cradle*, to be produced by Warner Bros., and has just finished another book provisionally called *Astounding Days*. Just published in the 'Mysterious World Series' is *A.C. Clarke's Chronicles*.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

2 December 1987, 7-9 pm — **Lecture**

REMINISCENCES OF BLUE STREAK

C.H. Martin

Members only. Please apply for ticket, enclosing SAE, in good time.

3 February 1988, 7-9 pm — **Lecture**

ENCOUNTER WITH HALLEY'S COMET

Prof. J.A.M. McDonnell

Members only. Please apply for ticket, enclosing SAE, in good time.

5 March, 1988, 10.30 am — **Visit**

UNIVERSITY OF SURREY

A tour of the UoSAT Spacecraft Engineering Unit for BIS members. Further details from: Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose SAE. Numbers will be restricted so please apply in good time.

9 March, 1988, 7-9 pm — **Lecture**

HOTOL–A SPACEPLANE FOR EUROPE

G.P. Wilson

Members (plus one guest) only. Please apply for ticket, enclosing SAE, in good time.

23 March, 1988, 10-4.30 — **Symposium**

HISTORY OF BLACK KNIGHT

An all-day Symposium. Refreshments will be provided and as numbers are limited early registration is advised.

19 April, 1988, 10-4.30 — **Symposium**

DIRECT BROADCAST BY SATELLITE

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

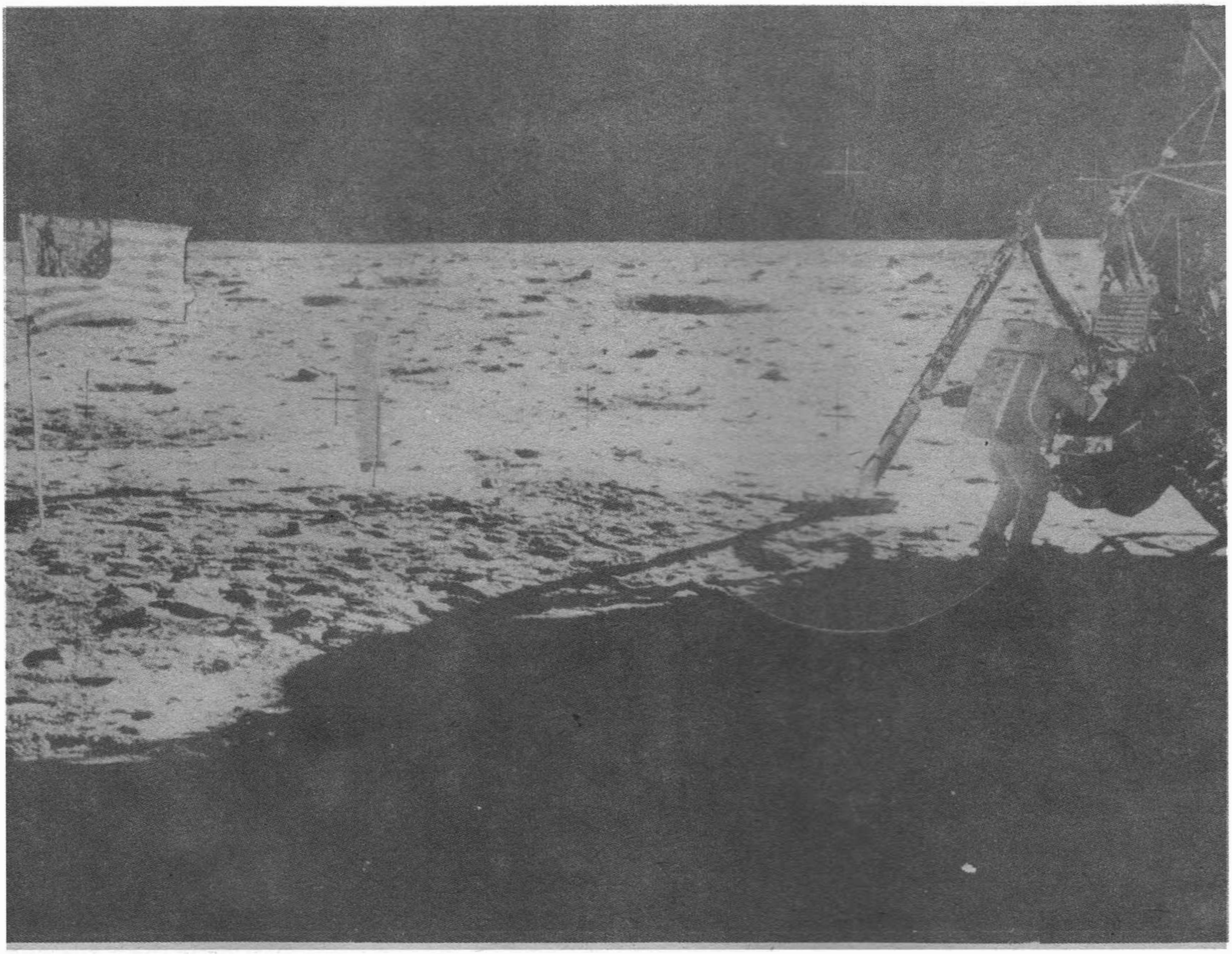
Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

CORRESPONDENCE



Frame number AS11-40-5886 which is believed to be the only 70mm Hasselblad lunar surface photograph of Neil Armstrong during the Apollo 11 EVA.
Space Frontiers

4132

Armstrong On The Moon

Sir, I was most interested to read the letter from Mr Keith Wilson (***Spaceflight***, August 1987, p. 296) in which he identifies one Apollo 11 "still" photograph which apparently shows Neil Armstrong on the Moon.

While appreciating that there is unlikely to be positive proof that photograph AS11-40-5886 shows Armstrong, it must surely behove the Society to obtain a copy of the photograph from NASA and print it in ***Spaceflight*** together with an enlargement of the relevant portion. I have often felt that history will judge the absence of a clear photograph of the first man on the Moon as the most absurd and inexplicable omission in the exploration of space. The publication of the photograph identified by Mr Wilson could therefore be of some considerable historical significance.

GEOFFREY BOWMAM
Belfast, N.Ireland

Sir, I felt readers would like to see what is believed to be the only 70mm Hasselblad lunar surface photograph of Neil Armstrong during the Apollo 11 EVA. It is frame number AS11-40-5886 which was described very well by Mr. Keith Wilson in the August issue of ***Spaceflight***. I enclose a full frame photograph and an enlargement of what is believed to be Mr Armstrong. All the photographs taken before and after AS11-40-5886 agree with the descriptions given by Mr Wilson.

Many thanks should go to the personnel at NASA Goddard's National Space Science Data Center in providing photographic services. Searches through the 70mm photographic catalogue on the Apollo 11 flight have shown no more photographs of Mr Armstrong except for his shadow and reflection in Mr Aldrin's faceplate.

GREGG LINEBAUGH
Maryland, USA

Sir, My letter published in ***Spaceflight***, August 1987, pp. 296-7 identified Apollo 11 commander Neil Armstrong on the lunar surface. The accompanying photograph shows this particular 70mm Hasselblad frame.

I believe that this frame is one of a sequence of photographs taken by lunar module pilot Aldrin which show a panoramic view of Tranquility Base. Armstrong is seen working at the Modularised Equipment Stowage Assembly, possibly packing or sealing the lunar sample return containers.

KEITH T. WILSON
Strathclyde, Scotland

CORRESPONDENCE

Supporting Britain's Space Future

Sir, The biggest blow this decade to the future of UK space potential is the Prime Minister's rejection of the vital budget increase proposed by Roy Gibson for the British National Space Centre. This event is underscored by the various exciting possibilities of recent years, such as Hotol, which may now fall to other countries to produce and benefit from. The many letters in ***Spaceflight's*** correspondence columns show that BIS members feel keenly disappointed in this matter, while Ralph Lorenz gives the excellent suggestion of writing to your MP.

Would it not be a valid proposition for the prestigious British Interplanetary Society to throw its weight behind a concerted effort, organised by a voluntary committee, designed to gather evidence of popular discontent, petitions, letter-files, supportive statements by industrial and scientific experts etc., and present it systematically, maintaining a continuous pressure upon not just our local MPs but on Parliament as a whole and the Cabinet and Prime Minister in particular? Such a coordinated effort may or may not achieve any actual result; but it is my belief that something should be done, that most BIS members would be prepared to sign something or write if only organised, and that many members are in a good position to canvass industry and seats of learning and thus bring to bear people and organisations outside the Society, for the common good.

Unfortunately, long experience has shown that nothing gets accomplished without some united front, and while I have mixed feelings on the topic of "pressure groups" in political contexts, the issue at hand cuts across all political divisions and policies and is concerned with nothing less than the presence of the UK in space-oriented technological fields for the next generation and longer.

PETER W. MILLS
Kent, UK

Ed. *The British Interplanetary Society together with people and organisations outside the Society have been in unison in opposing the UK Government's present stance. The BIS has a unique record for promoting awareness of the importance of space for Britain, Europe and the international community. The publication of* ***Spaceflight*** *is one such well-recognised example of the Society's efforts and is only a part of its programme.*

Readers can add their own contribution to that of the Society by discussion and making their opinions known. The value of a letter to their local MP should not be underrated. Individual letters can be much more effective than an organised petition. They call for individual replies and get noticed. Many years ago, Parliament's lack of concern with space was explained by one MP when he said that his postbag was full of people's problems but space was never one of them. Readers have it in their hands to change that – just for the price of a postage stamp.

MP Acknowledges BIS Efforts

Sir, Thank you for kindly sending me recent issues of the ***Spaceflight*** magazine. Thank you also for extending the courtesy of looking after me at your recent SPACE '87 Exhibition. I congratulate you on its success. I referred to it in my questions to Kenneth Clarke last week.

DAVID ATKINSON, MP
House of Commons

Ed. *The following extract is from* Hansard *October 28, 1987 Oral Answers:*

Space Plan

Mr. Atkinson asked the Chancellor of the Duchy of Lancaster when he expects to make a statement on his space plan.

Mr. Kenneth Clarke: The Government have decided not to increase public expenditure on space above the current level, which is already running at £100 million per year.

Mr. Atkinson: Will my right hon. and learned Friend confirm that the British space industry has yet to be formally consulted on the space plan? When his hon. Friend the Under-Secretary of State visited the Space 87 exhibition in Brighton earlier this month, was he not impressed by the presence of the French space industry, which receives far more recognition and support from its Government than does our industry, and by the fact that it is far larger and employs more people as a result? Will my right hon. and learned Friend bear that in mind when he goes to The Hague next month?

Mr. Clarke: My hon. Friend says that the industry has not been formally consulted, but I think that most leading industrialists in this sector are in regular contact with the British National Space Centre. I am already having discussions with many people in the industry and I intend to continue discussions in the coming months to get our strategy clear. There is certainly heavy French participation in the European Space Agency and the French are pressing particular programmes. We have to collaborate with them as essential partners in many areas but we must make sure, with them, that we are spending our money wisely on objectives of mutual advantage.

First Civilian in Space

Sir, The first civilian in space was Konstantin Feoktistov, a spacecraft designer (Voskhod 1, October 1964), and the first American civilian in space was a test pilot on Gemini 8 (March 1966) called – Neil Armstrong!

Both before and after the *Challenger* tragedy we had constant reiteration by the media of the asserting that Christa McAuliffe would be, and then would have been, the first civilian in space. ***Spaceflight*** (Milestones, October 1987, p. 57) committed the same error.

RAY WARD
London, UK

Spaceflight and *JBIS*

Sir, For 1988 I have decided to double my pleasure by subscribing to both ***Spaceflight*** and ***JBIS***; this will also enable me to avoid disappointment when I apply for journals too late. I missed the Soviet issue of ***JBIS*** earlier this year under such circumstances.

T.J. WAYNE
Kent, UK

Ed. *The Journal of the British Interplanetary Society (JBIS) may now be ordered for 1988 at the much reduced price of £22.00 (US$36.00) by members of the BIS.*

Spaceflight

Sir, I must commend you on your incredibly succinct and wonderful reporting of the past and present history of space flight and Man's attempts to be a significant part of it (***Spaceflight***, October 1987). I am so glad that I became a member. Keep up the good work.

ROBERT SHAW
New York, USA

CORRESPONDENCE

A 'Barnes Wallis' Shuttle?

Sir, In the late 1920's and mid 1930's Barnes Wallis invented and applied geodesics to the construction of airships and aircraft. Complete airframes were derived in curvilinear form to evolve an articulated structure without internal chords, diagonals, or bulkheads in which all the members were placed as geodesics of the boundary surface. Wings, fins, and tail planes were all formed from a uniform cross section light alloy of standard format.

Since the airframe withstood all of the linear and torsional stresses, the covering only needed to support overall aerodynamic loads and traditional cellulose doped fabric was used and stretched clear of the mainframe by means of carefully placed wooden spacer strips.

The whole system was extremely light and immensely strong – the first structure built for test purposes was loaded up to 13 'g' without failure. In fact this structure could not be tested to failure as the machines did not then have sufficient capacity – an anecdote often quoted by Wallis. This geodesic structure had one unique advantage. All members were equally loaded and if one or more were damaged, stresses were equally shared out among the rest. Many World War II airmen owed their lives to this unique characteristic of the Wellington bomber.

Having worked on these machines and their descendants and seen this construction in detail, I would suggest that by using modern materials this form of construction could be easily adapted to spaceplanes and the second generation shuttles.

For a given structure weight the cost savings would be enormous. Chemical milling and computerised cutting of metal slabs would be replaced by precision rolled and extruded standard sized girders bent to the required geodesic forms – a basically cheap process.

The original fabric covering would find its modern counterpart in thin, high temperature alloy sheeting bonded to the geodesic mainframe with high temperature synthetic resins. The material could be light alloy or steel.

This thin sheeting uniformly supported and stressed would form the base onto which the normal heat resistant cladding could be bonded by methods now well established. The normal tile separation allows for thermal expansion. A shuttle fabricated by this method could be made at much lower cost than present systems allow – and it could be made with relatively low skilled assembly labour.

If the weight saving was sufficient then even greater cost savings might be achieved by the use of inexpensive alloyed steels. These would preserve their strength at higher temperatures than light alloys. This would permit the use of thinner tiles or slates of heat resistant material – and therefore partly recover the weight penalty of using such steels. This would confer real long life reusability.

The second generation shuttle should be designed to function at the lowest possible total launch cost. Capital costs in terms of materials, labour and assembly processes form a large part of this total cost.

Additionally, the second generation shuttle must have as much integral tank structure as possible, and geodesic construction allows the maximum possible internal enclosed volume for a given prescribed overall structure weight. This was borne out in practice by the Wellington – it achieved double the payload and twice the range (for a given all-up weight) as did its projected contemporaries.

Again modern methods of tank construction could allow integration of a fuel tank system inside a wing structure whereby the tank stresses were due to the fuel load and vehicle accelerations – and nothing else.

Geodesic construction was phased out because the linen fabric covering was highly inflammable and (later on) of insufficient strength to be able to withstand flight speeds in excess of 400 mph. These disadvantages would not be manifested in a modern system using a thin metal sheath carry a heat resistant tile covering.

Any principle proven by past experience and capable of being updated by modern materials is well worth further study if it materially reduces the cost of operating reusable space vehicles. I think that the Wallis geodesic system of airframe construction using modern materials could do just that!

A.T. LAWTON
Middx, UK

Black Brant Launch

Sir, I am a new BIS member and am very satisfied with the Society. Its publication ***Spaceflight*** will help me with my studies in engineering and with improving my English.

In the January 1987 issue of ***Spaceflight*** a picture of a Black Brand X launch appears at the beginning of J. Powell's article "Black Brant X – A Canadian Export". I take the launch pad to be the Italian San Marco Platform in the Indian Ocean, 5 km off Malindi, Kenya, from which eight scientific satellites have been launched since 1967. Cound you please confirm my supposition? What was the date of launch of the rocket shown in the photo?

FRANCO MOCCI
Casazza, Italy

The following information has been provided by Joel Powell:

Although the photograph was not provided by myself, I do indeed know when it was taken. The picture shows the launch of one of the two Nike-boosted Black Brant sounding rockets (called the Black Brant VIII) from the San Marco Platform on February 15-16, 1980 to observe the total eclipse of the Sun.

NASA launched a total of seven sounding rockets from the San Marco Platform on those two days to study the solar corona and changes induced in the Earth's atmosphere caused by the temporary disappearance of sunlight in the zone of totality. The source of this information is the May 1980 issue of ***Spaceflight***, vol 25, p.192.

Eight Booster Version of Energia

Sir, An eight booster version of Energia with an upper third stage should have a more powerful core stage. It would be reasonable to assume a thrust increase from 800 tonnes to some 1200 tonnes obtained from five uprated engines each one delivering 240 tonnes and working for two thirds of the period of the original two-stage version. The third stage would then use a single engine of the same type and the thrust ratings of the stages would be: First : 7600 tonnes; Second : 1200 tonnes; Third : 240 tonnes. The corresponding values for the Saturn 5 are: Saturn 5 SIC : 3430 tonnes; S11 : 518 tonnes; SIVB : 103 tonnes.

The burn time for the strap-ons would be three minutes if we take the Isp of 380 seconds given by A.T. Lawton [1] or 2½ minutes if a more conservative value of 320 seconds is taken. (For comparison note that Saturn 5 first stage burn time was 2½ minutes). The burn time for the core stage would be eight minutes if Isp $\simeq$ 480 seconds [1] and this would also be the time to reach LEO (for the two stage Energia).

Maximum acceleration for the two-stage version just before strap-on separation would range between 4.4 and 4.7 g depending on burn time and assuming no thrust reduction to limit acceleration.

In a three-stage version based on the above assumptions, 80 tons of fuel would be required to get the third stage to LEO or parking orbit for a burn time of $\sim$ 160 seconds. From such a rough analysis and comparing the thrust with the Saturn 5 which had a third stage (SIVB) thrust of 100 tonnes and could

deliver 120 plus tonnes to a parking LEO prior to engine restart, one can conclude that a three stage Energia with eight strap-ons should have the capacity of placing over twice the Saturn 5 payload in LEO especially when considering higher specific impulses for the engines. So a lifting capability of as much as 300 tonnes to LEO can be achieved, as estimated by A.T. Lawton [1].

Saturn 5 delivered over 45 tonnes to the Moon; so the same should apply for a four strap-on Energia with a piggyback third stage (probably the same as the SL-16 second stage) delivering some 120-150 tonnes of thrust. An eight strap-on version should be able to send over 100 tons to the Moon, putting a "Novij Mir" core in lunar orbit.

M.G. HASSAN
S.R.C. Baghdad, Iraq

Reference
1 A T Lawton, "Energia – Soviet Super Rocket", ***Spaceflight***, Vol.29 pp 285-289, 1987

Cosmonaut Viktorenko

Sir, Readers of ***Spaceflight*** may be interested in the following biographical details about Soviet cosmonaut Alexander Viktorenko (call-sign "Vityaz"), who recently commanded the Soviet-Syrian Soyuz TM-3 flight to Mir.

Viktorenko is the first military test pilot known to have been selected for cosmonaut training in 1978, the other known 1978 recruits being six flight engineers and one civilian test pilot (Igor Volk). The *Izvestiya* newspaper [1] revealed that at some unspecified point in his cosmonaut training Viktorenko was the victim of a freak accident during an exercise in an isolation chamber. He unsuspectingly flipped a timer switch which had mysteriously come under an electrical charge of 220 volts, the shock leaving him unconscious for six hours. Viktorenko badly burnt both hands in the accident and seriously injured his head in the ensuing fall. These injuries were grave enough to prevent him from flying for the rest of his life, but Viktorenko persevered and through countless medical check-ups fought his way back to the pilot ranks and was eventually allowed to resume cosmonaut training.

The same *Izvestiya* article states that Viktorenko once trained as a member of "back-up crews" with veteran cosmonaut Vitaliy Sevastyanov. Since the two do not seem to fit in any of the still undisclosed back-up crews for Salyut 6 and 7, it is more likely the article actually refers to a support crew assignment for one particular mission. Since Sevastyanov had apparently quit active cosmonaut training after his 1975 Salyut 4 mission, his reinstatement as a cosmonaut trainee at a later date indicates a shortage of younger cosmonauts for the flight in question. Such a situation arose in late 1980, when most active cosmonauts were preparing for Salyut 7, forcing the Soviets to resort to a blend of old veterans and 1978 rookies to fly and back-up the Soyuz T-3 bonus flight to Salyut 6. The Soyuz T-3 crews included veterans like Oleg Makarov (prime flight engineer), Vasiliy Lazarev (back-up commander) [2, 3] Konstantin Feoktistov (medically disqualified as prime researcher cosmonaut only shortly before launch) [2, 3], all of whom had been considered retired, and 1978 rookies Gennadiy Strekalov and Viktor Savinykh (prime and back-up researcher cosmonauts) [2], who normally would not have been in line for a mission assignment just two years after their selection. In this context, Sevastynov (a 1966 veteran) and Viktorenko (a 1978 rookie) appear to be logical candidates for two of the Soyuz T-3 support crew slots (flight engineer and support commander respectively), the researcher cosmonaut still remaining open to speculation. The isolation chamber accident must have occurred some time after 1980, which explains why Viktorenko never appeared on a Salyut-7 mission. After his recovery he was paired with Alexander Alexandrov to first back up the 1986 Kizim-Solovyov mission and then fly the Soyuz TM-3 visiting flight.

The other two Soviet rookie cosmonauts who became known in 1987 are Alexander Laveikin (Soyuz TM-2 prime flight engineer) and Anatoliy Solovyov (Soyuz TM-3 back-up commander). In a departure from normal practice, Laveikin (1987 selection) never trained as a back-up crew member before his Mir flight, Soyuz TM-2 being his first assignment [4]. As for Solovyov (1976 selection), the Soviets hinted Soyuz TM-3 was not his first back-up assignment [5], but no further details were released. The Soyuz TM-2 reserve engineer was Alexander Serebrov [6], who probably stayed teamed up with his original Soyuz T-8 crew commander Vladimir Titov for his back-up post. The two are likely to become Mir's next resident crew, replacing Romanenko and Alexandrov this month (December).

BART HENDRICKX
Kapellen, Belgium

References
1 Izvestiya, July 23, 1987, p 3
2. The Soviet Cosmonaut Team, G. Hooper, GRH Publications, 1986
3. Nauka i Zhizan, November 1981, p 124-129
4 Pravda, February 6, 1987, p 3
5 Izvestiya, July 22, 1987, p 3
6 Radio Moscow Domestic Service, July 25, 1987, 18 00 GMT

How Vostok Cosmonauts Landed

Sir, In the paper "The Evolution of the Vostok and Voskhod programmes', published in ***JBIS***, January 1985, it is stated that "all six Vostok cosmonauts landed by parachute away from the DM".

The accompanying photograph, taken from a TV report of the landing of Vostok 6, shows Valentina Tereshkova and a woman ground crew member in the centre, the Vostok DM in the background and the cosmonaut's (ejection) seat in the foreground. This seems to suggest that the seat was taken out of the DM after landing and that, consequently, Tereskhova landed inside the Vostok 6 DM.

LUCIEN VAN DEN ABEELEN
The Hague, Holland

CORRESPONDENCE

Soviets Could Visit NASA/ESA Space Station

Sir, Space activities at the planned NASA/ESA space station will be constrained by the low orbital inclination (28.5 deg) currently anticipated. At first glance, visiting missions from higher latitude launch sites (e.g., Tyuratam in the USSR, at 46 N) would appear to be ruled out. There may, however, be a way for the Soviets to operate at the lower inclination, using the four-stage SL-12 (Proton-D) booster to carry Soyuz-TM and Progress vehicles into LEO.

Nominally, an SL-4 booster carries the Soyuz-TM or Progress (both weigh about 16,000 lb) into a 51.6 deg inclination orbit at 200-240 km. This involves launching from Tyuratam ("Baikonur") at an azimuth of 63 deg (27 deg north of due east) to avoid early overflight of Chinese territory.

Plane changes of any substantial size are costly in delta-V to the tune of about 440 ft/sec per degree. A typical manned spacecraft rarely has delta-V capability to make even one or two degrees plane change (and then it would not be able to deorbit!). Altitude changes are easier.

Beyond the SL-4, the USSR has a more powerful booster, the Proton, in service since 1965. The three-stage version (SL-13) carries up to 42,000 lb into a 51.6 deg inclination orbit; the four stage version (SL-12) carries a "D" injection stage and up to 10,000 lb of (escape) payload, or 4400 lb to GEO. The SL-12 booster was originally designed to be man-rated for the still-unacknowledged Zond manned circumlunar missions of the 1967-1970 period but no manned flights were performed then, or since.

During studies for space commercialisation, the Glavkosmos organisation in Moscow concluded that a four-stage SL-12 could place 12,100 lb into a 28.5 deg inclination orbit. This involves a standard SL-12 three-stage ascent and a fourth stage burn at first equator crossing to perform the plane change (instead of the nominal injection onto a GEO transfer orbit).

This performance already allows injection of an off-loaded Progress freighter into an SS-compatible orbit. The 16,000 lb Progress contains 5,000 lb of dry/wet cargo plus manoeuvring propellant scaled to its full mass. Off-loading 3,900 lb of cargo would create a vehicle weighing 12,100 lb (of which 1,100 lb is cargo), and the resulting pro-rated propellant savings would add an additional 100-200 lb of cargo. Simplified tankage structure on a modified Progress not intended to carry wet cargo could save an additional 200-300 lb, resulting in a dry cargo capability of 1,400-1,600 lb. In terms of urgent space parts or medical supplies brought to the SS, this capability could be extremely interesting.

For Soyuz-TM operations in SS-compatible orbits, the Glavkosmos level of 12,100 lb requires substantial upgrading. Several options are available:

(a) Launch due east (azimuth 90 deg), thereby increasing the benefit from the Earth's rotation and reducing the required plane change at the equator by almost six degrees. The heavier payload (a Soyuz-TM) would require off-loading some of the fourth stage propellant. My initial calculations indicate that such a mission would allow about 6900 ft/sec of delta-V, which could place a manned Soyuz-TM into an inclination as low as 30 degrees. To complete a rendezvous with the space station, the vehicle would need to first rendezvous with a tug or other high-delta-V spacecraft for the remaining plane change; perhaps the NASA OMV could conduct this service.

(b) Shape the SL-12 ascent profile for a sub-orbital trajectory which is circularised during the equator plane change burn. The first three stages could insert the fourth stage plus payload at a much lower altitude than standard (near 100 km versus the nominal 200 km) and the vehicle could coast to an apogee near the equator; without the subsequent manoeuvre it would re-enter over the southern Pacific. But the plane change burn could easily accommodate an orbit-raise burn as well. In this way a fully fuelled fourth stage plus Soyuz-TM could be inserted, and the result would be 7800 ft/sec of delta-V, placing a manned Soyuz-TM into a 28.5 deg inclination orbit at 220-400 km.

Option (a) is simple in that the SL-12/13 ascent profile is unaffected, although ground tracking and range safety issues (with diplomatic overtones) are raised. Option (b) is somewhat more complex, involving significant requalification of ascent vehicle dynamics, but its surprising pay-off is correspondingly spectacular.

A nominal SL-12/13 injection places the first southbound equator crossing between Kwajalein and Samoa. Use of a due east launch azimuth would move this point to about 150E, between Guam and the Solomons. Excellent tracking coverage of the plane change burn is available.

The use of Proton SL-12's for manned sorties to the NASA/ESA space station is entirely feasible, since the booster's availability through the 1990's has been asserted by Glavkosmos, along with its economy of use (the quoted launch price is $30M). The same is true for Soyuz-TM.

Visiting Soviet three-man crews could spend weeks or months at the SS. The Soyuz-TM on-orbit lifetime is currently six months when parked.

Landing requirements are interesting, and it appears that the most optimal thumpdown point for the Soyuz-TM is northern Australia (with Mexico as an alternate). On the other hand, the Soviets may wish to exercise their backup option of ocean splashdowns.

In conclusion, the opportunity for Soviet manned visits to a NASA/ESA facility at 28.5 deg inclination cannot be ruled out as impossible due to hard spacecraft/booster constraints. Proper diplomatic efforts could enable such missions to take place as long as near-term (and short-sighted) engineering decisions do not overlook their possibility. The advisability of further studies of these options is indicated.

JAMES OBERG
Texas, USA

Photo Essay

Sir, A slight error crept into the copy of my EVA photo essay in the September issue of ***Spaceflight*** and I would like to ask you to run the following comment in the correspondence section to head off any eagle-eyed reader who may wish to take me to task!

The photograph in the upper left corner on p.329 depicts astronaut Bruce McCandless during one of the EVA's on Mission 41B, not the Solar Max repair effort on 41C. The picture is actually a 35 mm frame from the Cinema 360 Inc., motion picture "The Space Shuttle: An American Adventure". Although copyrighted by Cinema 360 Inc., the photo was released to the public by NASA Headquarters. The large photo on the following page was exposed by a 70 mm Hasselblad camera on the SPAS platform and was included for the unique perspective it demonstrates.

JOEL POWELL
Calgary, Canada

Ed. *We gratefully acknowledge letters from Roger Wheeler and Marc D. Rayhman correctly identifying the photo on p.329 and from Douglas Arnold pointing out the origin of the photo on p.330.*

Antarctic Ozone

The cataloging of trace molecules in the Earth's atmosphere has been advanced by the ATMOS experiment onboard Spacelab 3 during its 1985 Shuttle flight (see the September edition of this column). Late last year, as part of the US National Ozone Expedition, the ATMOS measurement approach was employed by a JPL team led by Dr. Crofton B. Farmer at McMurdo Station, Antarctica. The purpose of the expedition was to gather data which would bear upon the apparent depletion of the ozone in the atmosphere above the cold continent during the Antarctic spring and the processes which bring about this phenomenon. Writing in the September 10, 1987 issue of *Nature*, John Maddox provides an assessment: "Farmer's group has made the first accurate measurements of the presence of simple halogen compounds in the spring-time ozone hole in the Antarctic stratosphere..."

Ozone was discovered by the German-Swiss chemist Christian Schönbein (1799-1868) in about 1840. A peculiar smell, long noticed in the vicinity of electrical equipment, led Schönbein to his discovery and served as the basis for his choice of name, "ozone", derived from the Greek *ozein:* "to smell".

Although knowledge of ozone, a molecule consisting of three atoms of oxygen contrasted with the more abundant diatomic form of oxygen, originated as a consequence of industrial practices, nature had been producing this substance in abundance in its factory in the stratosphere. The French physicist Charles Fabry (1867-1945) showed, by spectroscopic methods, that ozone existed in the upper atmosphere.

In order to appreciate the role that ozone plays, it is helpful to recall some basic facts about atmospheric structure.

The most fundamental classification, for the present purposes, is the division of the atmosphere into zones of altitude. The zone nearest to Earth, the troposphere, is the stage where the daily drama of weather plays out. The vertical extent of the troposphere varies with season and location, but an average over time and place would locate the tropopause, the region of division between troposphere and stratosphere, at about 11 km. The tropopause tends to be lower over the poles and can even reach the surface.

By definition, the tropopause marks the altitude where atmospheric temperature ceases to decrease with altitude (it falls, on average, at about 6.5 degrees C per km in the troposphere), and some three-quarters of Earth's air lies beneath. Temperature remains nearly constant in the tropopause and then begins to increase with height in the stratosphere, reaching about zero degrees C at the stratopause, located approximately 50 km above the surface.

The stratosphere is the repository for most of the ozone in the atmosphere. The amount of this trace gas is highly variable, but the peak value is normally about 10 parts per million (ppm) in the altitude range of 25 to 35 km. Ozone is produced (and destroyed) in the stratosphere by photochemical reactions, and these processes, driven by solar ultraviolet photons, contribute to the temperature maintenance of the stratosphere. At ground level, ozone concentrations vary from 0 to about 1 ppm and become irritating to the eyes at 0.1 ppm. The photochemical reactions responsible for "smog" in some urban areas include the production of ozone as one of the culprits.

The interception of a large fraction of the solar ultraviolet photons that impinge on the upper atmosphere is, of course, the beneficial effect of the stratospheric ozone layer whose possible reduction is a cause for concern. Too much exposure to ultraviolet radiation can cause health problems for humans and other living organisms.

Astronomically speaking, the stratospheric ozone drives ultraviolet astronomers to construct their observational facilities above Earth's atmosphere; witness the International Ultraviolet Explorer (IUE) in Earth orbit and the ultraviolet spectrometer "observatories" onboard Voyagers 1 and 2. The presence of tropospheric water

The US National Ozone Team conducted scientific studies of the Antarctic atmosphere in September-October 1986. Shown at their base at McMurdo Station are three JPL members of the team (from left): David Petterson, Dr. Geoffrey Toon, and Dr. Barney Farmer. *NASA/JPL*

vapour, which absorbs infrared photons in many spectral regions, produces a similar effect on ground-based infrared astronomy. Needless to say, astronomers, in their alternate roles as biological entities, are quite happy to undertake the extra efforts required to circumvent the astronomical side effects induced by the precious substances of ozone and water vapour!

Continuing our vertical march through the atmosphere, we next reach the mesosphere (50 to 80 km), which does not factor into our ozone story but does harbour the rare and somewhat mysterious noctilucent clouds: so-named because they are visible in the evening, remaining illuminated by the Sun in their high perch after most atmospheric denizens have passed into darkness. The next zone, the ionosphere, reaches to about 500 km and contains several layers of electrons which are important in facilitating Earth-to-Earth radio communications. Again, an astronomical side effect is present – while significant endeavours in radio astronomy do take place from Earth-based sites, the ionosphere does attenuate through reflection waves longer than a few metres from celestial sources. Finally, we reach the exosphere and grade from there into interplanetary space.

The reduction in the amount of ozone over Antarctica in the springtime has been recognised only for the past few years, and the ozone "hole", contained within the Antarctic circulation, fortunately passed centrally over McMurdo Station on two occasions last year, September 15-22 and October 15-23, when the JPL team was present. The edge of the hole (maximum ozone gradient) was near the observational site three times: September 5-8, September 23-28, and October 6-13.

As one can surmise from the discussion above on the properties of the atmosphere, the causes of the ozone hole are not easy to determine. Farmer and his colleagues entertained three hypotheses in planning their series of observations. First is the dynamic hypothesis that ozone depletion might result from the upwelling of ozone-poor air from the troposphere. Such air would inherently be richer in methane and nitrous oxide, a condition which serves as a convenient mark of identification. Second, as suggested by L. B. Callis and M. Natarajan, ozone depletion could be caused by higher levels of nitrogen oxides resulting from high solar activity. Third, chlorine chemistry, with the possibility of significant human contribution, could be the cause.

The dynamic hypothesis was tested by looking for anomalously high concentrations of species such as methane and nitrous oxide in the stratosphere. Farmer's group employed the JPL Mark IV Michelson interferometer in their measurements of atmospheric spectra from McMurdo Station. This device is similar to the one on Spacelab 3 but is adapted to use on ground-based, balloon, and airplane platforms (the principal difference from the instrument used onboard Spacelab is that sampling rates do not have to be as high in subspace environments, thereby easing attendant data acquisition and processing requirements). Anomalous gas concentrations were not found, and this dynamic hypothesis was not confirmed.

The second hypothesis, solar cycle effects, also failed to be confirmed when measurements of the nitrogen oxides revealed that their concentration levels were actually lower than those usually seen at mid-latitudes, where no ozone hole has been observed. The principal atmospheric reservoirs of chlorine are hydrochloric acid and chlorine nitrate. The ratio of the concentrations of these two compounds during the early Antarctic spring (September) was quite different from that typical of lower latitudes, returning toward normal at the end of October coincident with the recovery of the ozone concentration. Also, the total amount of chlorine in the reservoirs increased from September to October, possibly from the evaporation of condensed chlorine compounds in polar stratospheric clouds. Thus, during the time of growth of the ozone hole, the JPL team observed that the chlorine chemistry of the Antarctic stratosphere was perturbed, and the total chlorine in gaseous reservoirs increased.

Since chlorine can arise from natural as well as human sources, it is important to attempt to identify its genesis. Hydrofluoric acid is only present in the atmosphere as a result of human activity, and at mid-latitudes the current ratio of hydrochloric acid to hydrofluoric acid is about four. Farmer and his colleagues measured this ratio in the Antarctic and found it to be the typical four, but the concentration of hydrofluoric acid was three times that observed in mid-latitudes. Clearly, anthropogenic sources are suspected to account for the increase in chlorine, and the correlation of the excess chlorine with ozone depletion may be causally significant. As Farmer and his colleagues conclude in their paper in *Nature* (September 10, 1987, pp. 126-130): "While this is not proof of a cause and effect relationship between halogenated source gases and the springtime ozone depletion, it is entirely consistent with such hypotheses".

The complexity of the entire subject precludes easy answers, but the search for answers goes on. The JPL team followed its ground-based efforts with a series of south polar flights in a DC-8 of NASA, and investigators from several countries are pursuing the goal of protection through understanding.

Thanks are due to Odell Raper of the JPL ATMOS project who provided information on this subject.

Internati

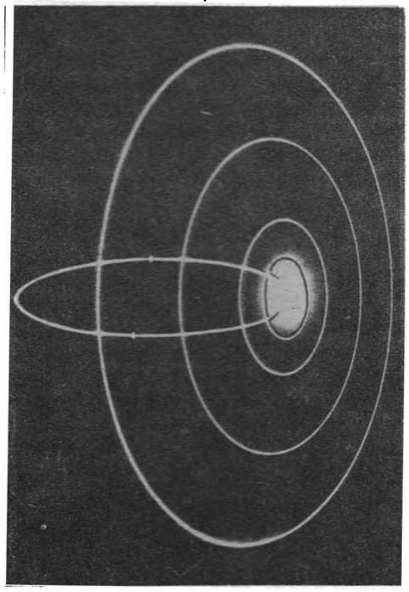
The recent apparition of Halley's comet was accompanied by an unprecedented outreach of scientific observations conducted from spacecraft and Earth-based facilities. The International Halley Watch (IHW) has backed up these observational programmes by carrying out an extensive set of ground-based astronomical coordination and archival functions. Astronomer Ray Newburn of JPL is head of the Western Hemisphere Lead Center for the IHW – Jurgen Rahe of the Astronomical Institute at the University of Erlangen-Nürnberg serves in a similar capacity for the Eastern Hemisphere Lead Center – and outlined current status and plans for the organisation.

Newburn said that a coordination effort had been attempted for the previous apparition of the comet when, in November of 1909, George C. Comstock distributed a circular which solicited world-wide astronomical cooperation during the impending passage of Comet Halley. The effort was not markedly successful, suffering from a late start and funding and communications problems, but a formal report was issued in 1915, five years after Comet Halley's closest approach to Earth.

The idea for Halley coordination during the 1986 apparition came from Louis Friedman, then of JPL, in 1979. In response, NASA initiated a study at the Laboratory that year to investigate the feasibility and objectives of such an endeavour. Three scientists from JPL, Newburn, Dr. Donald Yeomans, and Dr. Jay Bergstrahl, joined Friedman's study team.

During this phase, the support base was broadened by consulting with other astronomers, including Rahe and

Orbit of Halley's comet with the Solar System shown to the orbit of Neptune. *J. Baum*



onal Halley Watch

Dr. J.C. Brandt of NASA's Goddard Space Flight Center.

The next step was the formation in 1980 of a NASA Science Working Group chaired by Brandt with Newburn as vice-chair and Yeomans as executive secretary. The Working Group concluded that the IHW should be supported, and NASA selected JPL as the NASA Lead Center for the coordination effort. As Newburn says, "The IHW was underway". Friedman phased out of the effort in order to turn over leadership to cometary scientists, and Newburn became the (western hemisphere) IHW Leader. The Eastern Hemisphere Lead Center at Bamberg has been supported by the Federal Republic of Germany and led by Rahe. Although one might question the organisational wisdom of split responsibility, it has worked out well in practice for the IHW. The Infrared Astronomical Satellite (IRAS) had, similarly, a split project management (between the US and The Netherlands): an international arrangement that also functioned very well.

Major steps forward took place in 1982 with the issuance of the first IHW Newsletter and the all-important endorsement of the IHW organisation and goals by the International Astronomical Union (IAU), at its 18th General Assembly in Patras, Greece.

The IHW is organised around eight scientific disciplines, separated largely by the method or technology of observing that is employed within the discipline. Also called "Networks" reflecting the coordinative orientation of IHW, these disciplines are: astrometry, infrared studies, large-scale phenomena (eg, the cometary tails), near-nucleus studies (high resolution), radio studies, photometry and photopolarimetry, spectroscopy and spectrophotometry, and meteor studies. The last category is relevant because, as is well known, periodic comets gradually "load up" their orbits with meteoroids, and if the Earth passes close to the cometary orbit, as it does in Halley's case in May and October of each year, a flux of meteors enters our atmosphere.

Interesting coordination problems arose among the Networks. For example, observatories tend to assign observing time to infrared astronomers when the Moon is bright – generally moonlight does not affect their observations (observers concentrating on faint galaxies would most likely receive the dark sky around time of the new Moon). This, however, could create a disjunction between visible and infrared observers of Halley's comet, reducing the potential number of valuable simultaneous observations of the comet. However, the problem was ameliorated by planning joint visible and infrared observations when the Moon was below the horizon, even if, rising later, it curtailed visible observing; long exposures were not, in general, required.

Special efforts were made by the IHW to extend its support to space-based as well as ground-based observations. At a meeting in Padua, Italy in September 1981, IHW representatives (Newburn, Rahe, Yeomans) accompanied the NASA delegation and determined that they could usefully participate by providing navigational support, through astrometric measurements of the location of the comet, to the space missions (see the June 1986 'Space at JPL' for details of this work).

Cometary scientist Ray Newburn of JPL is co-leader of the International Halley Watch.
NASA/JPL

The Padua meeting was the first of the meetings of the Inter-Agency Consultative Group (IACG), as it was later named, and at the November 1982 meeting of the IACG in Dobogok, Hungary, the IHW was invited to attend future meetings as a non-voting member. The final link in the space connection was forged at the third IACG meeting in Kagoshima, Japan in December 1983 when it was agreed that all of the Halley missions would place their data in the IHW archives.

When Comet Halley arrived – it was recovered on October 16, 1982 with the 5m telescope at Caltech's Palomar Observatory and passed closest to the Sun on February 9, 1986 – the observers were ready. Approximately 1000 professionals and a similar number of amateurs obtained something like 50,000 observations of the comet (a trial run of IHW procedures was done by observing Comet Crommelin in March 1984, and a significant scientific effort was mounted by the IHW in support of NASA's flyby of Comet Giacobini-Zinner on September 11, 1985 with the International Cometary Explorer spacecraft; see "Through the Tail of a Comet" in the November 1984 edition of ***Spaceflight***).

The picture of Halley's comet that has developed from these observations continues to evolve, but, in brief, the nucleus can be characterised as being bigger, darker, and more irregular than expected. The nucleus measures approximately 15 x 8 x 8 km rather than the 5 km, generally spherical object that most expected. The amount of sunlight reflected by the nucleus is small, in the range of three per cent to four per cent, making it as dark as the black rings of Uranus.

The IHW is now engaged in collecting observational data ("send it in now!" admonishes Ray Newburn) and compiling it for achiving and publication. The printed version of the IHW report will be published in 1989 and consist of approximately six volumes of 500 or so pages each. It will be organised chronologically and have at least an entry for each observation in the IHW data base. Half tones of the better pictures and some spectra are planned for inclusion (a companion volume devoted to images will be issued under the editorship of Brandt).

The most complete rendering of the IHW data base will appear, in mid-1990, on standard compact disks (CD). The 20 or so CDs should contain approximately 600 megabytes of information each, 90 per cent of which represents imaging (image data compression, similar to that employed by Voyager 2 at Uranus, will help to hold down the total data base, by about a factor of two). One CD (and one hard-copy volume) will be devoted to observations of Comet Giacobini-Zinner; the Comet Crommelin data (hard copy) was released in February 1986 in a quite different format.

Observations of Halley's comet for this apparition have not yet concluded. Astronomers, including some at the European Southern Observatory and the Kitt Peak National Observatory, plan to make photometric measurements of the comet in February 1988 after it emerges from the solar glare. At about 21st magnitude, it will still be easily visible in 1m telescopes with CCD detectors, and cometary activity should be at a low level this distance from the Sun. Thus, observers have the opportunity to settle the question of what is the rotational period of the nucleus of Halley's comet; some data have indicated 2.2 days, while others suggest a 7.4 day period. In the absence of a significant coma, this dichotomy seems susceptible of resolution.

Newburn was, of course, quite busy during the time of apparition and had to deny himself the pleasure of a cruise or other extended expedition to observe the comet. But on April 7, 1986, flying over the Mojave desert at 37,000 feet in a chartered 727, cometary scientist Ray Newburn paid his personal respects to Halley's comet as he observed it against the black sky for several hours with naked eye and binoculars. He finally found time to obtain professional observations of it in May 1987 at NASA's Infrared Telescope Facility in Hawaii.